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CHEMICAL DIAGRAMS;

OR,

CONCISE VIEWS

OF

MANY INTERESTING CHANGES

PRODUCED BY

CHEMICAL AFFINITY.

BY JACOB GREEN, M. D.

PROFESSOR OF CHEMISTRY IN JEFFERSON MEDICAL COLLEGE.

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P R E F A C E.

THE design of the following pages is to present to the chemical student some of the most important changes produced by the reciprocal action of bodies on each other, by the aid of diagrams. This method of illustration has been for a long time employed by the author in teaching the practical details of Chemistry, and it is now published at the earnest solicitation of his pupils, and also with a hope that it may be generally useful.

This volume is intended merely as a companion to more extended treatises on the science, in which the nature and peculiar properties of elementary substances are considered, and the numerous combinations which they form by uniting together, according to fixed and unvarying laws. Without the possession of such works, or without a good degree of familiarity with the leading principles

and the practical details of the science, this book can be of but little value.

Numerous methods have been devised for presenting clear and brief views of the phenomena which occur during chemical decomposition. When conciseness alone is the object desired, then the methods and the symbols employed by Berzelius will perhaps be found the most advantageous; but for the purpose of aiding those little conversant with the minutiae of modern chemistry, the plan here exhibited has been found preferable. As this work treats of nothing but known facts and established doctrines, the author can claim but little originality in its preparation.

To give more interest to the following pages, a few historical facts have been added, and some practical remarks on the detection of poisons.

CHEMICAL DIAGRAMS.

PART I.

OXYGEN AND ITS COMBINATIONS WITH ELEMENTARY BODIES.

OXYGEN GAS was discovered both by Mr. Scheele and Dr. Priestley. Its atomic weight or combining proportion is 8. It may be obtained from several sources, but the substances commonly employed are black oxide of manganese, nitre, and the chlorate of potash. From the black oxide of manganese it is procured either by heating it to redness in an iron bottle, or by putting it, in fine powder, into a glass retort, with an equal weight of strong sulphuric acid, and then heating the mixture with a lamp.

Explanation of the processes.

An atom of manganese weighs 28, and there are three oxides of this metal, which are constituted as follows:

	Manganese.	Oxygen.
Protoxide, . . .	28 +	8 = 36
Deutoxide, . . .	28 + 12 =	40
Per, or black oxide, .	28 + 16 =	44

When the peroxide is exposed to a red heat, every 88 parts or two atoms are decomposed, 8 parts or one atom of oxygen gas escape, and 80 parts or two atoms of the deutoxide remain in the iron bottle. For every 88 grains of pure black oxide of manganese we thus obtain 8 grains of oxygen gas, or nearly 24 cubic inches.

The rationale of the process by Sulphuric Acid.—Every 44 parts or each atom of the peroxide gives off 8 parts or one atom of oxygen, and is thus converted into the protoxide of manganese, which unites with the acid and forms the sulphate of the protoxide of manganese.

Rationale of the process by Nitre or Nitrate of Potash.—When nitre is put into an iron bottle and heated to redness, it first melts, and then a large quantity of oxygen is evolved, the acid of the salt being decomposed. Every 102 parts of nitre contain

Nitric acid 54	{	Oxygen 8	—————	Oxygen gas.
		Oxygen 8	—————	Oxygen gas.
		Oxygen 8	—————	Hyponi- trous acid
		Oxygen 8	—————	
		Oxygen 8	—————	
		Nitrogen 14	—————	
Potash 48	{	Potassium 40	}	Potash
{	Oxygen 8			
<div style="display: flex; justify-content: space-between; align-items: center;"> 86 hypo- nitrite Potash. </div>				

Some chemists imagine that in this process only 8 parts of oxygen gas are produced, and not 16, as we have supposed above; their theory supposes that *nitrite*, and not hyponitrite of potash, is left in the iron bottle.

Rationale of the process by Chlorate of Potash.—When chlorate of potash is put into a small glass retort and heated with a spirit lamp nearly to redness, it is revolved into pure oxygen gas, and into the chloride of potassium, which is left in the vessel. The theory of the decomposition is as follows:—Every 124 parts of chlorate of potash contain

Chloric acid 76 \	{	Oxygen 8	} Chloride of Potass 76.
		Oxygen 8	
		Oxygen 8	
		Oxygen 8	
		Oxygen 8	
Potash 48	{	Chlorine 36	
		Potass 40	
		Oxygen 8	

From this explanation it appears that for every 124 grains of chlorate of potash used, 76 grains of chloride of potassium are produced, and 48 grains, or 141 cubic inches, of pure oxygen gas.

NITROGEN 14.

Nitrogen gas was discovered by Scheele, and also by two or three other experimentalists. It is prepared by burning phosphorus in a jar of atmospheric air inverted in water. Phosphoric acid is produced, and then rapidly absorbed by the water; the residual gas is impure nitrogen.

The following table exhibits the constitution of the compounds of oxygen and nitrogen by weight and volume.

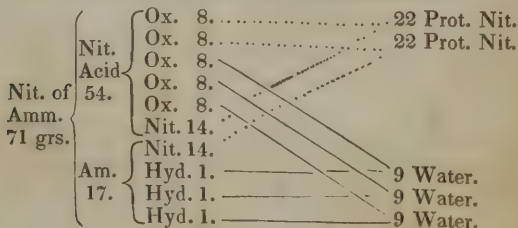
	By volume.		By weight.	
	Nitrog.	Oxyg.	Nitrog.	Oxyg.
Atmospheric air,	100	25	14	4
Protoxide of nitrogen,	100	50	14	8
Deutoxide of nitrogen,	100	100	14	16
Hyponitrous acid,	100	150	14	24
Nitrous acid,	100	200	14	32
Nitric acid,	100	250	14	40

In all the above compounds the oxygen is entirely condensed, except in atmospheric air and the deutoxide; in these there is no contraction of bulk whatever.

Protoxide of Nitrogen, 22.

The most striking properties of this gas were first ascertained by Sir H. Davy. It is prepared by exposing the nitrate of ammonia in a glass retort to the heat of a good spirit lamp, the salt is then resolved into water and the deutoxide of nitrogen.

Every 54 parts or one equivalent of real nitric acid (contained in 72 of the common liquid nitric acid) combine with 17 of ammonia, and give 71 of dry nitrate of ammonia, which is resolved by the heat into 27 parts of water and 44 of protoxide of nitrogen; as a 100 cubic inches of this gas weigh nearly $46\frac{1}{2}$ grains, 71 grains of the nitrate will give 95 cubic inches of this gas, (= 44 grains.) The following diagram shows the changes that are produced by the decomposition.



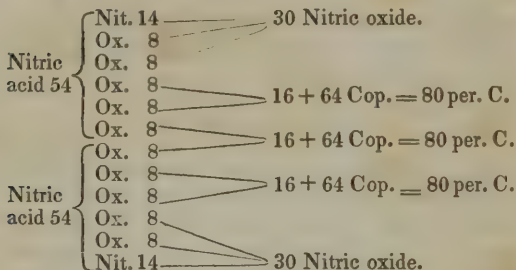
The first part of the table (to the left) represents the elementary composition of the 54 parts of nitric acid and the 17 of ammonia existing in 71 parts of the dry nitrate, and the other shows the new arrangement which these enter into, and the compounds produced. The three proportions of hydrogen in the ammonia combine with three of oxygen from the nitric acid, and the remaining proportions of oxygen come away with the nitrogen both of the nitric acid and the ammonia in the form of protoxide of nitrogen.—*See Reid's Chemistry.*

Deutoxide of Nitrogen, 30.

This gas was discovered by Dr. Hales. It is advantageously obtained by the action of nitric acid on metallic copper. For this purpose, copper clippings or turnings are put into a tubulated retort, and nitric acid diluted with one and a half times or twice its bulk of water is poured over them; an effervescence immediately commences, the liquid assumes a greenish blue colour, and the copper is dissolved; the deutoxide of nitrogen that is disengaged may be collected over the pneumatic trough.

In this process, every three equivalents of metallic copper decompose two equivalents of nitric acid, combining with the greater portion of the oxygen, and being converted into three equivalents of the peroxide of copper, each of these at the same time unites with one proportion of nitric acid, forming nitrate of the peroxide of copper, which remains in solution; the nitrogen of the two proportions of nitric acid which are decomposed comes away with the remaining oxygen in the form of deutoxide of nitrogen. The following diagram will con-

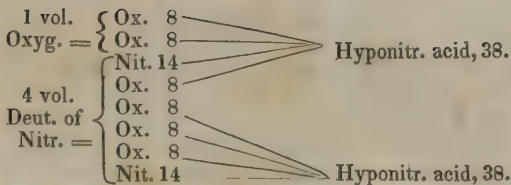
vey a more precise idea of the manner in which the copper reacts upon the nitric acid which is decomposed; the part to the left expressing the elementary constitution of the two proportions of nitric acid, while the other shows the manner in which they arrange themselves.



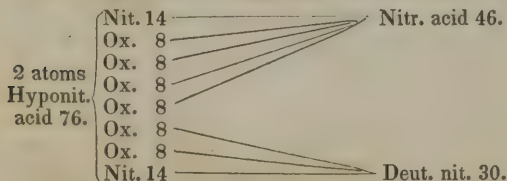
The solution of nitrate of copper that remains in the retort may be reserved for future experiments.—*Reid.*

Hyponitrous Acid, 38.

This compound was discovered by Gay Lussac. When an excess of deutoxide of nitrogen is added to oxygen in a glass tube containing a strong solution of pure potash over mercury, he found that 100 measures of oxygen gas combined with 400 of the deutoxide, forming an acid which united to the potash. The following diagram will illustrate this change. It will be recollected that one volume of oxygen contains 2 atoms or equivalents, and that the nitrogen and the oxygen in the deutoxide are under no condensation.



The hyponitrous acid has not yet been obtained in a free state; for when another acid is added to the hyponitrite of potash, the hyponitrous acid, instead of being dissolved in the water of the solution, suffers decomposition, and is converted into nitrous acid and deutoxide of nitrogen, which change may be thus explained.



Nitrous Acid, 46.

This acid seems to have been first examined in a pure form by Sir H. Davy. He made this compound by mixing two measures of deutoxide of nitrogen and one of oxygen, free from moisture, in a dry vessel previously exhausted by the air pump. The acid gas is distinguished by its deep orange-red colour. The following diagram shows the changes which take place in the above experiment.



Nitric Acid, 54.

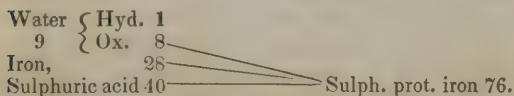
The chemical constitution of this highly important acid was first shown by the Hon. Henry Cavendish. It is obtained for commercial purposes, by decomposing the nitrate of potash by sulphuric acid. In this process, the materials are mixed so nearly in the proportion of two equivalents of sulphuric acid to one of nitrate of potash, that we may assume this to be the case in explaining the reaction which ensues. Every two equivalents of the common sulphuric acid (98) consist of two equivalents of water (18) and two of dry sulphuric acid (80); the nitrate of potash is composed of one equivalent of potash (48) and one of nitric acid (54). The dry sulphuric acid combines with the potash, forming bisulphate of potash, and the water goes to the nitric acid, forming the liquid which is condensed in the receiver; dry nitric acid not having hitherto been procured in a free state, as it is always decomposed when disengaged from any of its compounds if no water is present to condense it. The annexed diagram gives a clearer view of the theory of the action, the part to the left showing the composition of the materials, and the other the products of the decomposition.—*See Reid.*

Common sulphuric acid 98	{	Water 9	-----	72 com. nit. acid.
		Water 9	-----	
		Dry Ac. 40	-----	128 bis. of potash.
		Dry Ac. 40	-----	
Nitrate of potash 102	{	Nit. Ac. 54	-----	
		Potash 48	-----	

HYDROGEN i.

The nature and leading properties of this gas were first pointed out by the Hon. Henry Cavendish. It is readily prepared by pouring dilute sulphuric acid on small pieces of iron or zinc.

Rationale of the process.—That the hydrogen which is evolved from the above materials must be derived from the decomposition of the water, is evident from the fact, that of the three substances—iron, nitric acid and water—the last is the only one known to contain hydrogen. The product of the operation, besides hydrogen, is sulphate of the proxide of iron, if iron be used, or of the oxide of zinc, if zinc be employed. The following sketch will illustrate the changes which occur in this process.



From the above it is obvious that for every 9 grains of water decomposed, 1 grain of hydrogen will be set free, 8 grains of oxygen and 28 grains of iron will unite to 40 grains of sulphuric acid, and produce 76 grains of sulphate of the protoxide of iron. A similar calculation may be employed when zinc is used, by substituting the atomic weight or combining proportion of zinc, which is 34, for that of the iron.

Hydrogen unites with oxygen in two proportions, and with nitrogen only one combination has yet been discovered. These are as follows:

	By volume.		By weight.	
	<i>Hyd.</i>	<i>Oxyg.</i>	<i>Hyd.</i>	<i>Oxyg.</i>
Protoxide of Hydrogen,	2	1	1	8
Deutoxide,	1	1	1	16
	<i>Hyd.</i>	<i>Nitrog.</i>	<i>Hyd.</i>	<i>Nitrog.</i>
Ammonia,	3	1	3	14

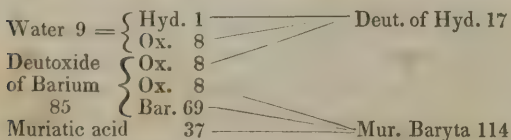
Protoxide of Hydrogen or Water, 9.

The great importance of water as a natural and as an artificial agent, both mechanical and chemical, must be exceedingly obvious; and a knowledge of the exact proportions in which oxygen and hydrogen gases unite so as to form the liquid, is intimately connected with much of our chemical reasonings. The composition of water, both by the weight and volume of its elements, has therefore been determined with the greatest care by the most skilful chemists. There can be no doubt that it is formed by the two gases in the ratio above stated. Thus if a mixture of them, either by weight or measure in the above proportions, be inflamed in a glass tube by an electric spark, they entirely disappear, and water is the sole product. If one volume of oxygen is mixed with three of hydrogen, one volume of hydrogen remains after the explosion; and a mixture of two volumes of oxygen and two of hydrogen leaves one volume of oxygen. These are some of the data from which it is inferred that oxygen gas is just 16 times as heavy as an equal bulk of hydrogen; and as no compound of these substances is known which has a less proportion of oxygen than water, it is therefore supposed to contain but one atom of each of its constituents. As it requires two measures or volumes of hydrogen and only one measure of oxygen to form water, it is concluded that

an atom of oxygen is just half the size or bulk of an atom of hydrogen.

Deutoxide of Hydrogen, 17.

This compound was discovered by Baron Thenard. It would be inconsistent with our plan to enter into the minute details necessary for preparing this curious substance. It is made by the action of the deutoxide of barium on water acidulated with muriatic acid; the deutoxide of barium loses one atom of its oxygen, which, instead of escaping as free oxygen gas, unites to the water and forms the deutoxide of hydrogen; the deutoxide of barium is thus converted into the protoxide or baryta, which then combines with the acid. This change may be thus shown.



Hydrogen and Nitrogen, Ammoniacal Gas, 17.

Impure ammonia was known to the Alchemists, but it seems first to have been noticed in a gaseous state by Dr. Priestley and Mr. Scheele. A convenient method of preparing this gas is by applying a gentle heat to the strong aqua ammonia of the shops, contained in a glass retort, and catching the gas which evolves over mercury. Liquid or aqua ammonia is merely water changed with the gas, and on applying heat the gas escapes. Another process is also used for obtaining this gaseous compound. Equal weights of muriate of

ammonia in powder and well burned quick-lime, just slaked, are put into a glass or iron vessel, heat is applied, and the temperature gradually increased as long as a free evolution of the gas continues.

In this process the lime combines with the muriatic acid of the muriate of ammonia, and disengages ammoniacal gas, which escapes, while a reaction at the same time takes place between the lime and the muriatic acid, and the products are, chloride of calcium and water. The diagram gives a view of the decomposition.

<i>Before decomposition.</i>			<i>After decomposition.</i>	
54 Mur. of Am.	{ Ammonia,	17	—	17 Ammonia.
	{ Mur. Ac. { Hyd. 1		—	9 Water.
		Chl. 36	—	
28 Lime, . . .	{ Ox. 8		—	
	{ Cal. 20		—	56 Chl. Cal.

The lime is employed in larger quantity than is absolutely necessary for the decomposition, in order that it may be more easily effected; it is unnecessary to represent the excess in the diagram, however, as it is not decomposed.—*See Reid.*

The foregoing is the explanation commonly given, but perhaps the following is quite as satisfactory.

54	{ Ammonia 17	
Mur. Am.	{ Mur. Ac. 37	
Lime,	28	— Mur. Lime 65.

The water used in slaking the lime is not supposed to undergo any change on either theory.

Nitrate of Ammonia, 71.

Ammonia unites to nitric acid and forms the salt called nitrate of ammonia, the substance used for ob-

taining protoxide of nitrogen. It is readily formed by neutralizing dilute nitric acid with carbonate of ammonia and evaporating the solution.

CARBON 6.

This element is found pure in nature under the form of the diamond. In union with other substances it is very extensively diffused. The following table exhibits its combinations with the three elementary bodies already mentioned.

	Weight.		Volume.	
	<i>Carb.</i>	<i>Oxyg.</i>	<i>Carb.</i>	<i>Oxyg.</i>
Protoxide of Carbon,	6	+ 8 = 14	2	1
Carbonic Acid,	6	+ 16 = 22	1	1
Oxalic Acid, or	12	+ 24 = 36	2	3
Hypo-carbonic Acid, }				
	<i>Carb.</i>	<i>Nitrog.</i>	<i>Carb.</i>	<i>Nitrog.</i>
Cyanogen,	12	+ 14 = 26	2	1
	<i>Carb.</i>	<i>Hyd.</i>	<i>Carb.</i>	<i>Hyd.</i>
Olefiant gas,	12	+ 2 = 14	2	2
Fire damp,	6	+ 2 = 8	1	2

Carbonic Oxide or Protoxide of Carbon.

The real nature of this compound was first pointed out by Mr. Cruickshank.

There are several processes by which this inflammable gas may be procured, most of which consist essentially in depriving carbonic acid of half its oxygen by heating it with some substance which has a great affinity for this element. The best method, perhaps, consists in exposing dried chalk to heat with an equal weight of iron filings, and a small quantity of charcoal,

(from a fifth to a tenth part,) in an iron tube or retort, and raising its temperature speedily in a good furnace or open fire, till the gas begins to come. The materials should be reduced to as fine a state of division as possible, and the temperature must never be allowed to fall, otherwise the gas soon ceases to come, or carbonic acid is disengaged instead of carbonic oxide.

In this process the chalk (which is a carbonate of lime,) parts with its carbonic acid on exposure to heat, and the iron and carbon mixed with it take away one proportion of oxygen, converting it accordingly into carbonic oxide. Either the iron or the carbon would do separately, but when they are both taken, there is less risk of the product being contaminated with carbonic acid. The following is the rationale of the process when chalk and carbon are used, the carbonic acid being supposed to be expelled by heat from the chalk.

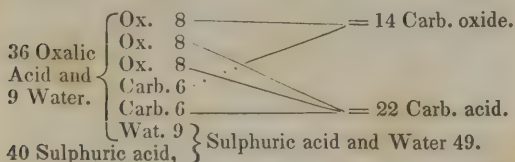
<i>Before decomposition.</i>		<i>After decomposition.</i>	
Carb. acid, 22 =	Carb. 6	14 = Carb. oxide.	
	Oxy. 8		
	Oxy. 8	14 = Carb. oxide.	
Carbon, 6			

When iron filings and chalk are employed, then the following change takes place.

Carb. acid, 22 =	Carb. 6	14 = Carb. oxide.	
	Oxy. 8		
	Oxy. 8	36 = Oxide iron.	
Iron, 28			

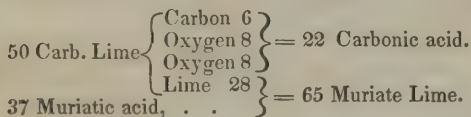
Carbonic oxide may also be formed by decomposing oxalic acid or deutoxalate of potash by sulphuric acid; equal measures of carbonic acid and carbonic oxide are produced, and on removing the former by a solution of

potash or lime water, the latter is left in a state of purity. To understand the theory of this process, it must be recollected that oxalic acid is composed of an atom of carbonic acid and an atom of carbonic oxide—that it cannot exist unless in combination with water or some other substance, and that the sulphuric acid unites with the water and the potash. The following diagram will illustrate the decomposition of oxalic acid by the sulphuric acid, and may be readily applied to the compounds of oxalic acid with the different bases.



Carbonic Acid, 22.

This substance was discovered by Dr. Black. It is easily prepared by the action of dilute muriatic or sulphuric acids on carbonate of lime; the acid unites to the lime and the carbonic acid escapes; no heat is required in the process.



Carbonic acid forms three compounds by uniting to ammonia.

1st. Carbonate of ammonia = 1 atom carbonic acid and 1 ammonia.

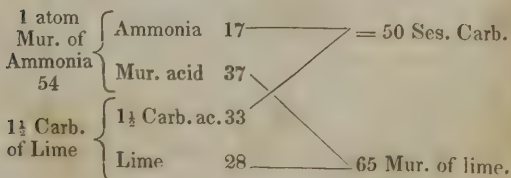
2nd. Bicarbonate of ammonia = 2 atoms carbonic acid and 1 ammonia.

3d. Sesqui-carbonate of ammonia = $1\frac{1}{2}$ of carbonic acid and 1 of ammonia.

Carbonate of ammonia may be obtained by mixing two measures of ammonia (one equivalent) with one measure of carbonic acid (one equivalent) over mercury, the two gases immediately combining and condensing in the form of a white dry powder.

Bicarbonate of ammonia may be prepared by passing a stream of carbonic acid gas through a solution of common carbonate of ammonia till it ceases to absorb any more, and evaporating the liquid by a very gentle heat.

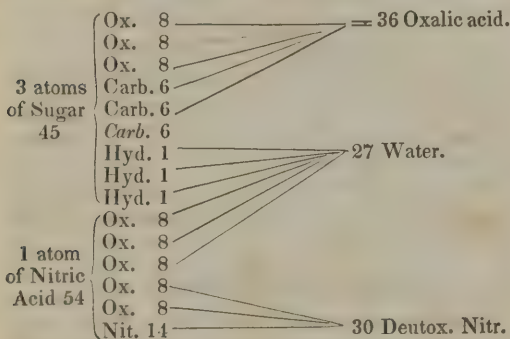
The sesqui-carbonate of ammonia is prepared by mixing muriate of ammonia and carbonate of lime, both reduced to a fine powder, and exposing the mixture to a strong heat in an iron pot, covered by a dome or head, on which the sesqui-carbonate condenses as it is sublimed. The proportions of muriate of ammonia and carbonate of lime are one part of the former to one and a half of the other; double decomposition takes place, muriate of lime remains in the vessel, and the sesqui-carbonate sublimes. The following diagram will illustrate the changes.



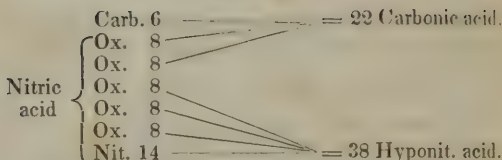
This compound, which is the carbonate of ammonia of the shops, always contains a portion of water.

Hypo-carbonic Acid or Oxalic Acid, 36.

The true constitution of this body seems to have been first established by Berzelius. It occurs abundantly in certain plants, in combination with lime or potash. It is commonly prepared by digesting sugar in five or six times its weight of nitric acid; very complicated changes ensue, which produce not only the oxalic acid and generate water, but also form deutoxide of nitrogen, carbonic acid, hyponitrous acid, and probably formic acid. The following diagram will illustrate some of these changes.



One atom of carbon in the above rationale is not accounted for but by decomposing two atoms of nitric acid instead of one, as in the diagram; then we should form with this atom of carbon, one atom of carbonic acid and one of the hyponitrous acid, thus:



It follows, therefore, on the foregoing supposition, that 3 atoms of sugar = 45 and 2 atoms of nitric acid = 108, produce by a new arrangement of their elements after decomposition

1 Oxalic acid	= 36
3 Water	= 27
1 Deutoxide of Nitrogen	= 30
1 Hyponitrous acid	= 38
1 Carbonic acid	= 22 = 153

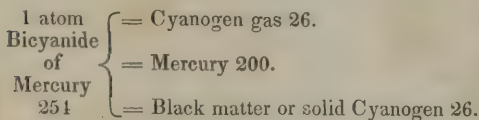
The mellitic acid found in the honey-stone, according to Wöhler and Leibig, is formed exclusively of oxygen and carbon, in the ratio of 4 atoms of carbon = 24 and 3 atoms of oxygen = 24.

The croconic acid of Gmelin is another vegetable product, which consists of 5 atoms of carbon = 30 and 4 of oxygen = 32.

Carbon and Nitrogen, Cyanogen gas, 26.

This compound, which is sometimes called the bicarburet of nitrogen, was discovered by Gay Lussac. It is readily made by heating the bicyanide of mercury, carefully dried, in a small glass retort, with a good spirit lamp. In this operation the bicyanide of mercury is resolved into its elements, the cyanogen escapes as a gas, and the mercury is sublimed; a dark brown matter like charcoal remains in the retort, which consists

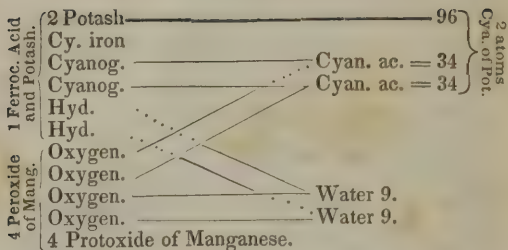
of the same ingredients as the gas itself. It is scarcely necessary to add the following diagram to illustrate the operation.



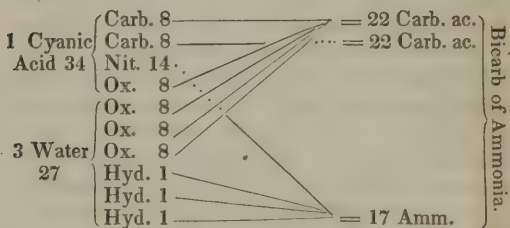
Cyanogen, though a compound body, has a remarkable tendency to unite with elementary substances; thus, with oxygen and hydrogen it forms highly interesting and very peculiar acids.

Cyanogen and Oxygen, Cyanic acid, 34.

The existence of cyanic acid was first clearly demonstrated by Wöhler. It is composed of one atom of cyanogen and one of oxygen. It is made by mixing ferrocyanate of potash with the peroxide of manganese, in fine powder, and exposing them to a low red heat. The cyanogen of the ferrocyanic acid receives oxygen from the manganese, and is converted into the cyanic acid, which then combines with the potash and forms the cyanate of potash. This is then separated from the impurities by boiling alcohol. The precise rationale of the above process has not been satisfactorily determined, but the following diagram will illustrate some of the changes.



The cyanic acid is then separated from the potash by another acid which is highly concentrated; the acid vapours being collected in a receiver surrounded with ice. The cyanic acid is characterized by being converted into the bicarbonate of ammonia on the addition of water. The following diagram will illustrate this change.



The above change is effected by simply boiling the aqueous solution of the cyanate of potash. It is obvious from the above sketch that the hydrous cyanic acid alone, which consists of one atom of real acid and one of water, cannot undergo the same change as its aqueous solution.

Cyanate of Ammonia, 60.

The action of cyanic acid on ammonia is peculiarly interesting. The true nature and relations of this salt were first established by Dr. Wöhler. He found it to be precisely identical in its composition with an animal product called urea. It may be prepared either by the action of aqua ammoniæ on the cyanate of lead, or when dry ammoniacal gas is mixed with the vapour of hydrous cyanic acid. In this last process a white crystalline solid is formed, which is probably a dicyanate; this gently heated gives off ammonia, and the cyanate of ammonia remains, in which all the properties of the animal principle of urea may be recognised. The following exhibition of the elements which enter into the constitution of the two substances, will render the above change obvious.

<i>Urea.</i>		<i>Cyanate of Ammonia.</i>	
2 Carbon = 12		Cyanic acid { 1 Oxygen = 8	
		34 { 2 Carbon = 12	
2 Nitrogen = 28		1 { 1 Nitrogen = 14	
		Ammonia { 1 Nitrogen = 14	
4 Hydrogen = 4		17 { 3 Hydrogen = 3	
		Water 9 { 1 Hydrogen = 1	
2 Oxygen = 16		1 { 1 Oxygen = 8	
<hr/> 60			<hr/> 60

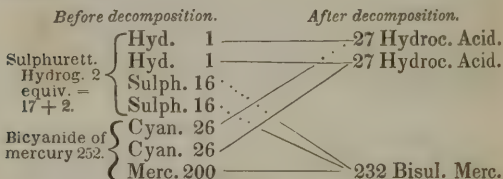
There are other acids formed by the union of oxygen and cyanogen; one is the fulminic or cyanic acid of Leibig, and the two cyanuric acids of Wöhler.

Cyanogen and Hydrogen, Prussic acid, 27.

The prussic or hydrocyanic acid was discovered by Scheele. It may be prepared by a number of processes. A good one consists in filling a glass tube, placed hori-

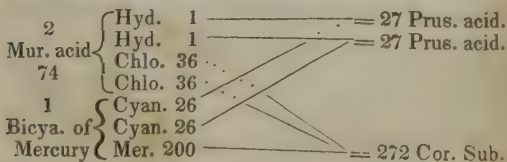
zontally, with fragments of the bicianide of mercury, and then passing a current of dry sulphuretted hydrogen gas slowly through it. The instant the gas comes in contact with the cyanide, double decomposition ensues, and hydrocyanic acid and bisulphuret of mercury are formed.

One equivalent of the bicianide requires two equivalents of sulphuretted hydrogen for its complete decomposition, and two equivalents of hydrocyanic acid and one of the bisulphuret of mercury are obtained. The following diagram gives a view of the action that takes place.

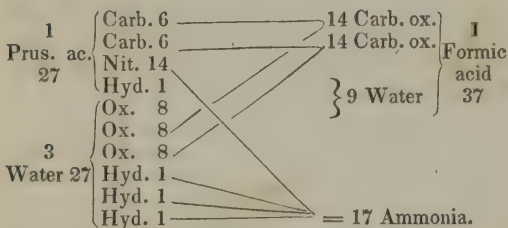


The hydrocyanic acid obtained in this manner is very strong and pure, and equal in weight, when carefully collected, to about a fifth part of the bicianide employed.

Another process is by heating bicianide of mercury in a glass retort with concentrated muriatic acid; the hydrogen of the acid unites to the cyanogen of the cyanide, and corrosive sublimate remains in solution, thus:



The vapour of prussic acid, as it rises during the above process, is always mixed with moisture and muriatic acid, from which it must be freed. It is highly necessary in the preparation of prussic acid to avoid all excess of muriatic acid, otherwise it resolves itself into ammonia and formic acid; the muriatic acid seems to occasion this change by its affinity for ammonia. It will at once be perceived that one atom of prussic acid and three of water contain the exact elements for forming one of ammonia and one of formic acid, which last is composed of two atoms of carbonic oxide and one of water.

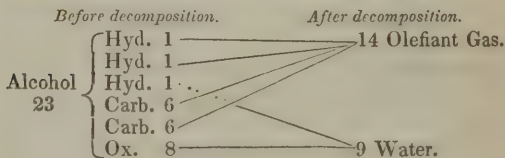


Carbon and Hydrogen, Olefiant gas, 14.

This gas was discovered by the associated Dutch Chemists. It is prepared by mixing one part by measure of alcohol with three of strong sulphuric acid in a glass retort, and exposing the mixture to a gentle heat. The retort should not be more than a third full, and when only a small quantity of the gas is required, half an ounce of alcohol with a proper quantity of sulphuric acid will be found quite sufficient. A little ether is formed at first, and towards the end of the process, sulphurous acid, carbonic oxide, and the bihydruret of

carbon (another compound of carbon and hydrogen) are disengaged; the mixture also becomes quite black from the deposition of carbon, and is very apt to boil over.

To understand the nature of the changes that take place in this process, it must be recollected that every 23 parts, or one equivalent of alcohol, is composed of three parts of hydrogen (three equivalents) twelve of carbon (two equivalents) and eight of oxygen (one equivalent,) so that it may be regarded as a compound of one equivalent of water and one of olefiant gas, for the different elements are present exactly in the proportions necessary to form these compounds. The water then may be said to combine with the sulphuric acid, while the olefiant gas is disengaged; the new arrangement which the elements of the alcohol assume is represented in the following diagram.



The olefiant gas disengaged from each equivalent of alcohol at the commencement of the process, often combines with an equivalent of alcohol which is not decomposed, forming one equivalent of ether, which explains its appearance; the black colour which the liquid assumes afterwards, and the formation of bihyduret of carbon arise from the elements of the alcohol arranging themselves in a different manner, which will be readily understood from the annexed diagram.

	Before decomposition.	After decomposition.
Alcohol 23	{ Hyd. 1	8 Bihyd. of Carb.
	{ Hyd. 1	
	{ Hyd. 1	
	{ Carb. 6	6 Carb. precipit.
	{ Carb. 6	
	{ Ox. 8	9 Water.

But no sooner is the carbon precipitated than it begins to react upon the sulphuric acid, taking one equivalent of oxygen from it, and being converted into carbonic oxide, while the sulphuric acid becomes sulphurous acid in consequence of losing this proportion of oxygen, a small quantity of carbonic acid is also formed towards the end of the process.

Light Carburetted Hydrogen gas, or Fire Damp, 8.

The true nature of this gas was first ascertained by Dalton. It occurs abundantly in nature, but there is no convenient method of making it artificially. It is composed of two atoms of hydrogen and one of carbon.

The researches of M. Faraday have enriched the science of Chemistry by the discovery of several other combinations of carbon and hydrogen.

BORON, SILICON, ZIRCONION.

The three elementary bodies above named are analogous in many respects to carbon. The combinations which they form by uniting to the substances already mentioned, do not require any particular illustration.

PHOSPHORON OR PHOSPHORUS, 12.

Phosphorus was discovered by Brandt. The method now used of obtaining it from bones, was first proposed

by Scheele. Calcined bones, of which phosphate of lime constitute nearly four-fifths, are reduced to powder and digested for some time in sulphuric acid; a slightly soluble sulphate of lime, and a soluble biphosphate of lime, are thus produced, which, on the addition of boiling water, are easily separated from each other by filtration. The biphosphate of lime is then decomposed by means of charcoal, the oxygen of the phosphoric acid forming with the charcoal, carbonic acid and the phosphorus escaping in a free state.

The combinations of phosphorus with the substances already mentioned are numerous, but the exact atomic constitution of these compounds cannot be considered as fully established; it is therefore expedient to represent these combinations in the manner heretofore adopted in chemical works, till further experiments shall finally establish their exact constitution.

The following table shows the composition of the compounds of phosphorus with oxygen and hydrogen.

	<i>Phosphorus.</i>		<i>Oxygen.</i>	
Phosphoric Acid,	12	+	16	= 28
Pyro-phosphoric Acid,	12	+	16	= 28
Phosphorous Acid,	12	+	8	= 20
Hypo-phosphorous Acid,	24	+	8	= 32
	<i>Phosphorus.</i>		<i>Hydrogen.</i>	
Proto-phosphuretted hydrogen,	12	+	2	= 14
Phosphuretted hydrogen,	12	+	1	= 13

Phosphoric Acid and Pyro-Phosphoric Acid, 28.

These compounds afford an instance of a fact of great interest in reference to the atomic theory, which is, that two substances which differ essentially in their chemi-

cal properties may be formed by the union of the same ingredients in the same proportions; such compounds are said to be *isomeric*.

Phosphoric and pyro-phosphoric acid may be prepared by burning phosphorus under a dry receiver of air or of oxygen gas; a white flaking powder is produced, which is anhydrous pyro-phosphoric acid; this on exposure to the air for some time absorbs moisture, and become phosphoric acid. A red heat converts phosphoric acid into pyro-phosphoric acid, and water reconverts the latter into the former, which in a free state only exists in solution. Both these acids form characteristic salts by uniting to the different bases.

Phosphorous Acid, 20.

This compound is generated in various ways. When sticks of phosphorus are exposed to the air in a funnel they become oxidated, moisture is absorbed, and an oil-like liquid drops through the funnel, which is the acid in question. Its salts are the *phosphiles*.

Hypo-phosphorous Acid, 32.

This compound was discovered by Dulong. It is produced by the action of water on the phosphuret of barium; mutual decomposition ensues; the elements of water uniting with different portions of phosphorus give rise to the formation of three compounds, phosphuretted hydrogen, phosphoric acid, and hypo-phosphorous acid: the former escapes as a gas; the two latter combine with the baryta, generated by the oxygen of the water and the barium. The hypo-phosphate of baryta being soluble, is easily separated by a filter from the insoluble phosphate of baryta; sulphuric acid being then added

to the hypo-phosphate of baryta, sulphate of baryta precipitates and the acid remains in solution.

Oxides of Phosphorus.

A white crust is formed on the sticks of phosphorous when they are kept for some time under water, and a red coloured matter often remains after its combustion; both these substances are supposed to be oxides, but their real nature has not been determined in a satisfactory manner.

Phosphorus and Hydrogen.

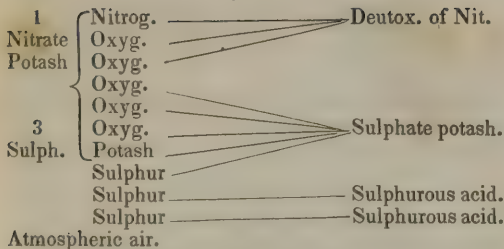
Proto-phosphuretted hydrogen gas and phosphuretted hydrogen are the only compounds of these two substances generally admitted, and much uncertainty still prevails respecting their exact constitution; we shall therefore adhere to the old method of stating their composition.

Proto-phosphuretted Hydrogen gas, 14.

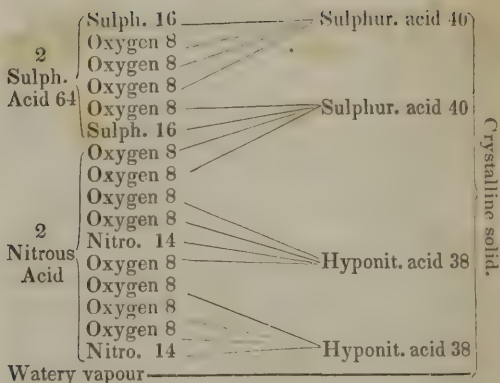
This compound was discovered by Sir H. Davy. It consists of one atom of phosphorus and two of hydrogen, and is made by heating solid hydruretted phosphorous acid in a close vessel. The chemical changes which give rise to its production are thus explained by Sir H. Davy. For every four atoms of phosphorous acid two atoms of water are decomposed. The six atoms of oxygen unite with three of phosphorus, forming three atoms of phosphoric acid; while the remaining atom of phosphorus attaches itself to the two atoms of hydrogen and forms one atom of proto-phosphuretted hydrogen gas. These changes may be exhibited as follows:

Sulphuric Acid, 40.

This acid is said to have been discovered by Basil Valentine. It is made by burning sulphur and nitre in a large leaden chamber, the floor of which is covered to the depth of several inches with water. The nitric acid of the nitrate of potash gives oxygen to a portion of the sulphur and converts it into sulphuric acid, which combines with the potash of the nitre and forms the sulphate of potash, while a greater part of the sulphur forms sulphurous acid by uniting with the oxygen in the air of the chamber. The nitric acid, on losing a portion of its oxygen, is converted into the deutoxide of nitrogen, which at the moment of its separation unites to the oxygen of the air and becomes the nitrous acid. The gaseous compounds present in the leaden chamber are, therefore, sulphurous acid, nitrous acid, atmospheric air, and a little watery vapour. The sulphurous acid and the nitrous acid are now absorbed by the water in the bottom of the chamber. The nitrous acid gives out two atoms of its oxygen to two atoms of sulphurous acid and converts them into two atoms of sulphuric acid, thus resolving itself into the deutoxide of nitrogen, which from its levity rises into the air of the chamber, combines again with two atoms of its oxygen, and again becomes nitrous acid. This then descends again into the water, and converts two more atoms of sulphurous acid into two of sulphuric, and again rises; and so on, until by the same process of combination and decomposition the whole of the sulphurous acid in the water is converted into the sulphuric acid. Some of these changes may be illustrated by the following diagram.



The above rationale was formerly given to the process, and it is probable that much of the sulphuric acid in the leaden chamber is formed in this manner. But there is always a crystalline solid produced by the union of nitrous acid, sulphurous acid, and watery vapour; and most chemists imagine that it is the decomposition of this solid by the water on the floor of the chamber that the sulphuric acid is produced. Different views have been taken of the constitution of this solid. Gay Lussac's opinion appears the most plausible. By the mutual reaction of moisture, sulphurous acid and nitrous acid, the crystalline compound is formed, which he supposes to consist of sulphuric acid, hyponitrous acid, and water. When this solid falls into the water of the chamber it is instantly decomposed, sulphuric acid is dissolved, and nitrous acid and the deutoxide of nitrogen escape. The nitrous acid thus set free, as well as that produced by the deutoxide absorbing oxygen from the air, is again intermixed with sulphurous acid and humidity, and this gives rise to form a second portion of the crystalline solid which undergoes the same change as the first. The production of the crystalline compound as above may thus be illustrated.



Now when the crystalline solid drops into the water, the sulphuric acid is absorbed, and the two atoms of hyponitric acid undergo decomposition, being resolved into nitrous acid and deutoxide of nitrogen, as shown by the diagram under the head of hyponitrous acid.

Sulphurous Acid, 32.

This acid seems first to have been noticed by Stahl. It may easily be prepared by depriving sulphuric acid of one atom of its oxygen. Nearly all the metals, with the aid of heat, have this effect; one portion of sulphuric acid yielding oxygen to the metal, and thus becoming sulphurous acid, while the metallic oxide at the moment of its formation unites with some of the undecomposed sulphuric acid, which thus becomes a sulphate. The best process is to place one part of mercury and two of sulphuric acid in a glass retort, and then apply heat. The changes are as follows:

1 Sulphur. acid 40	{	Sul. 16	Sulphurous acid 32.
		Ox. 8	
		Ox. 8	
		Ox. 8	
Mercury 200		Prot. merc. 208	} Sulphate Protox. Mercury.
Sul. acid 40			

Hyposulphurous Acid, 24.

This acid was discovered by Gay Lussac. It cannot exist permanently in a free state. It is procured by digesting sulphur in a solution of the sulphite of lime or any other sulphite. In this process an atom of the oxygen in the sulphurous acid unites to the sulphur, and thus produces 2 atoms of hyposulphurous acid; thus:

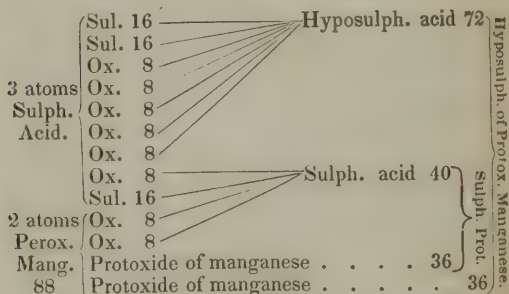
1	{	Sul. 16	Hyposul. acid 24.
Sulphurous		Oxy. 8	
acid 32		Oxy. 8	
Sulphur, . . . 16			Hyposul. acid 24.

It is remarkable that while the elements of hyposulphurous acid are in the ratio of 16 to 8, its equivalent or atomic weight is not 24, but 48. This is inferred from the fact that the quantity of this acid required to neutralize one equivalent of any alkaline substance is 48. From this it would seem that a single atom of hyposulphurous acid is formed of two atoms of sulphur and two of oxygen.

Hyposulphuric Acid, 72.

This acid was discovered by Gay Lussac and Welter. It is formed by transmitting a current of sulphurous acid gas through water containing peroxide of manganese in fine powder. The manganese yields oxygen to the sulphurous acid, converting one part of it into sul-

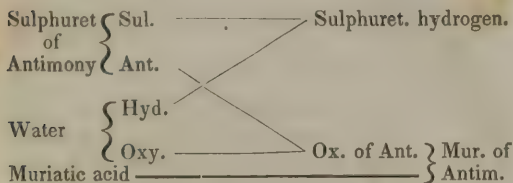
phuric acid and another part into the hyposulphuric acid, both of which unite to the protoxide of manganese. To the liquid, after filtration, a solution of baryta is added, which precipitates the protoxide of manganese and forms an insoluble sulphate of baryta with the sulphuric acid, and a soluble hyposulphate with the hyposulphuric acid. The hyposulphate of baryta is then decomposed by a quantity of sulphuric acid, exactly sufficient for precipitating the baryta, and the hyposulphuric acid is left in solution. The following diagram will illustrate some of these changes.



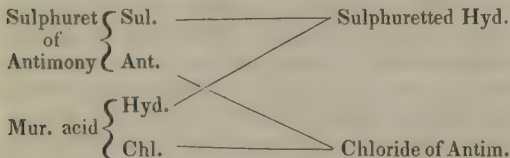
Sulphuretted Hydrogen, 17.

This gas was first investigated by Scheele. It is prepared by adding liquid muriatic acid and the sulphuret of antimony together and applying heat. In this process the water and the muriatic acid is probably decomposed, the hydrogen combines with the sulphur of the sulphuret, and escapes as sulphuretted hydrogen, while the oxygen unites to the antimony and forms the protoxide of antimony, which probably attaches itself to

some undecomposed muriatic acid. These changes may be illustrated thus:



Some chemists imagine that in the above process muriatic acid and not water is decomposed, and it is doubtful which explanation is the true one; thus:



Sulphuretted hydrogen is also made by the action of sulphuric acid on the protosulphuret of iron. A reaction takes place between every nine parts of water (one equivalent) and 44 (one equivalent) of the sulphuret of iron, the latter being composed of 16 of sulphur and 28 of iron. The oxygen of the water combines with the iron of the sulphuret, forming oxide of iron, with which one equivalent of the acid unites, converting it into sulphate of iron which remains in solution, while the sulphur and the hydrogen combine together to form sulphuretted hydrogen. The following diagram from Reid is intended to illustrate the decomposition.

9 Water.	{ Hyd. 1	-----	17 Sulph. Hydro.
	{ Ox. 8	-----	
44 Sulph.	{ Sul. 16	-----	
of iron.	{ Iron 28	-----	
40 Sulphuric ac.	40	-----	76 Sulph. of Iron.

Bisulphuretted Hydrogen, 33.

This compound was discovered by Scheele. It is made by boiling together equal parts of slaked lime and flowers of sulphur, with five or six of water, when a deep orange-yellow solution is formed, which contains the hydrosulphuret of lime with an excess of sulphur. This, on being gradually poured into a dilute solution of muriatic acid, deposits sulphur, and the sulphuretted hydrogen instead of escaping from the solution, unites with the sulphur so as to form the bisulphuretted hydrogen, which gradually subsides in the form of a semi-fluid matter like oil. From the facility with which this substance resolves itself into sulphur and sulphuretted hydrogen, its chemical history has been very imperfectly ascertained.

The combinations of sulphur with the other substances already mentioned do not fall under our present plan.

SELENION, 40, AND TELLURIUM, 32, (32-2.)

The above mentioned elementary bodies occur in very small quantities in nature. Selenion, or Selenium, as it is commonly called, was discovered in sulphur by Berzelius, and is analogous in many respects to that body. Tellurium was found by Klaproth in an ore of gold.

ARSENICUM OR ARSENIC, 38, (37-7.)

Arsenic is found in nature, but it commonly occurs in combination with cobalt, from which it is separated, on account of its volatility, by merely heating the ore. This process seems first to have been practised by Brandt. The following is a view of the combinations of arsenic with oxygen and hydrogen.

Arsenic. Oxygen.

Arsenious acid, 38 + 12 = $1\frac{1}{2}$ = 50

Arsenic acid, 38 + 20 = $2\frac{1}{2}$ = 58

Arsenic. Hydrogen.

Arsenuretted hydrogen, . . 38 + $1\frac{1}{2}$

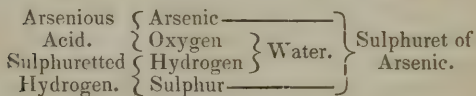
Solid arsenuretted hydrogen, 38 + 1

Arsenious Acid, 50.

This is the compound which sublimates when the arsenical ores are roasted, the oxygen of the air combining with the metal and producing the acid; or, as it is often called, the white oxide of arsenic. Every student should be familiar with the methods used for detecting this substance, as it is frequently administered as a poison. It does not fall within the plan of this little work to enter into all the details, but the following process is the most certain and the only necessary one that need be employed:—The fluids of the stomach in which the poison is commonly lodged, are in the first place to be freed from all organic substances which may interfere with the action of the test to be applied. This is readily done by boiling them with successive portions of pure or distilled water, then filtering the solution, and adding to it some acetic or muriatic acid. Through

this liquid sulphuretted hydrogen is to be passed; if arsenious acid is present, even in exceedingly minute quantities, a yellow colour will be produced, by the formation of orpiment or the yellow sulphuret of arsenic. This is at first partially suspended, but on boiling the fluid to expel the free sulphuretted hydrogen it subsides, and may easily be collected on a filter. On drying the sulphuret thus obtained, mixing it with dry fused carbonate of potash, and heating the mixture contained in a glass tube, to redness over a good spirit lamp, decomposition ensues, and the arsenic is revived on the cool part of the tube, in the form of a metallic crust, of an iron-gray colour externally, and of a crystalline structure internally. A few particles of this crust placed on red hot charcoal volatilizes as a white cloud, and gives out an alliaceous odour.

The following diagram will illustrate one of the changes which takes place in the above process.



Arsenic Acid.—This compound was discovered by Scheele. It is made by dissolving arsenious acid in strong nitric acid, mixed with a little muriatic, and distilling the solution to perfect dryness.

Arsenuretted Hydrogen.—This was also discovered by Scheele. It is prepared by digesting an alloy of tin and arsenic in muriatic acid.

Solid Arsenuretted Hydrogen was discovered by Davy and Gay Lussac. It is formed by the action of water on an alloy of potassium and arsenic.

Sulphurets of Arsenic.—There are at least two sulphurets of arsenic, realgar and orpiment; both occur in the mineral kingdom. Realgar is composed of one atom of arsenic and one of sulphur, and orpiment of one atom of arsenic and one and a half of sulphur; it is therefore a sesqui-sulphuret.

TIN OR STANNUM, 58.

This metal has been known from the earliest times. The only valuable ore of tin is the peroxide, from which the metal is obtained by heat and charcoal. There are but two oxides of tin, and they are thus constituted.

	<i>Tin.</i>	<i>Oxygen.</i>
Protoxide,	58 or 1 atom	+ 8 = 66
Deutoxide,	58 or 1 atom	+ 16 = 74

As both these oxides have some acid powers, they have been called the stannic and the stannous acids.

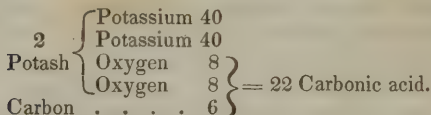
POTASSIUM, 40, (39-15.)

Potassium, the metallic base of potash, was discovered by Sir H. Davy, while investigating the electrochemical powers of the galvanic battery. It is commonly prepared by the action of iron or charcoal on pure potash at a high temperature. The theory of both processes is very simple.

$$\begin{array}{l} \text{Potash} \left\{ \begin{array}{l} \text{Potassium } 40 \\ \text{Oxygen } 8 \end{array} \right\} \\ \text{Iron } 28 \end{array} \Bigg\} = 36 \text{ Protoxide of iron.}$$

Perhaps the sesqui-oxide of iron may be formed in this operation, and then every two atoms of that metal

would decompose three of potash. When charcoal is used, the oxygen from two parts of potash unites with the charcoal and produces carbonic acid; thus:



The best process is to decompose the potassa by a mixture of iron filings and charcoal.

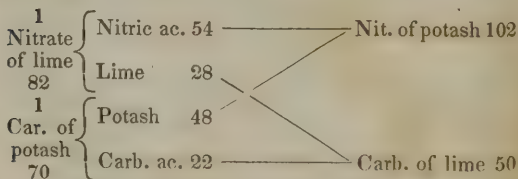
Potassium unites to oxygen in two proportions, thus:

	Potassium.	Oxygen.
Protoxide of Potassium,	40 or 1 atom	+ 8 = 48
Peroxide of Potassium,	40 or 3 atoms	+ 24 = 64

The compounds of potash or the protoxide of potassium, with the acids already mentioned, are many of them highly interesting.

Nitrate of Potash, 102.

This important salt, called in common nitre or salt-petre, occurs in nature; but it is commonly prepared by decomposing the nitrate of lime, an abundant natural production, with carbonate of potash or pearl ashes. The following is the rationale.



Carbonate of Potash, 50.

There are three salts formed by the union of carbonic acid uniting in different proportions with potash.

Carbonate of Potash,	48	or 1 atom	+	22	=	70
Bicarbonate of Potash,	48	„	+	44	=	92
Sesqui-carbonate,	48	„	+	33	=	81

Sulphate of Potash, 88.

This salt may be prepared by neutralizing the carbonate of potash with sulphuric acid, and is easily obtained from the residuum of the distillation of nitric acid, dissolving it in water and adding sub-carbonate of potash till the excess of acid is completely neutralized. The solution is then evaporated to expel part of the water, and small crystals of the sulphate are deposited on cooling. Carbonate of lime is occasionally employed instead of carbonate of potash to remove the excess of acid, continuing to add it to the solution of the bisulphate as long as any effervescence takes place. The following diagram shows the action that takes place, supposing all the potash to be in the state of bisulphate.

<i>Before decomposition.</i>			<i>After decomposition.</i>	
128	{	Potash 48	88	Sulph. potash.
Bisulph. potash.		Sul. acid 40		
	{	Sul. acid 40	22	Carbonic acid.
50 Carb. of lime.		Carb. ac. 22		
	{	Lime 28	68	Sulph. of lime.

Sulphuret of Potassium, 56.

It may be obtained pure by passing hydrogen gas over the sulphate of potassa; four atoms of water and one of the sulphuret of potassium will thus be generated.

1	Sulphur	16	} Sulphuret of Potassium 57
	Potassium	40	
Sulphate of Potash 88	Oxygen	8	} 4 atoms of Water - - - 36
	Oxygen	8	
	Oxygen	8	
	Oxygen	8	
4 Hydrogen gas 4	Hydrogen	1	
	Hydrogen	1	
	Hydrogen	1	
	Hydrogen	1	

SODIUM, 24, (23-3.)

This element was discovered by Sir H. Davy. It is obtained in the same manner as potassium. There are two oxides, which are thus constituted:

	<i>Sodium.</i>	<i>Oxygen.</i>
Protoxide of Sodium,	24 or 1 atom	+ 8 = 32
Peroxide of Sodium,	48 or 2 atoms	+ 24 = 72

The compounds of soda or the protoxide of sodium are very analogous to those of potash.

Carbonate of Soda.

There are three salts formed by the union of carbonic acid with soda.

	<i>Soda.</i>	<i>Carbonic Acid.</i>
Carbonate of Soda,	32 or 1 atom	+ 22 = 54
Bicarbonate of Soda,	32 “	+ 44 = 76
Sesqui-carbonate,	32 “	+ 33 = 65

Phosphate of Soda.

This is a very valuable salt. It is prepared on a large scale by neutralizing the biphosphate of lime, procured by the action of sulphuric acid on calcined bones, with

the carbonate of soda. The excess of phosphoric acid in the biphosphate combines with the soda of the carbonate and remains in solution, disengaging carbonic acid with effervescence, while the phosphate of lime having now lost its excess of acid becomes insoluble and is precipitated. In the following diagram representing the action that takes place, two equivalents of acid are supposed to be combined with one of lime in the biphosphate.

Carbonate of Soda	{ Carb. acid 22—22	Carbonic acid.
	{ Soda 32 }	60 Phosphate of Soda.
Biphosphate of Lime	{ Phos. acid 28 }	
	{ Phos. acid 28 }	56 Phosphate of Lime.
	{ Lime 28 }	

The biphosphate of lime, however, is generally prepared with a much greater excess of acid, and every additional equivalent which it contains enables it to decompose another equivalent of the carbonate of soda. The latter ought to be added till the solution can render a test paper green, as a slight excess of alkali favours the crystallization. The solution is filtered to separate the phosphate of lime, and evaporated afterwards till a pellicle appears on its surface, when it may be set aside to crystallize.—*See Reid.*

Sulphate of Soda, 72.

This is the common glauber salt. It is procured in large quantities as a residue in the process for forming muriatic acid, which consists in adding sulphuric acid to chloride of sodium. The following diagram exhibits the chemical changes.

1 Sulphate	{	Hydrog. 1	—	37 Muriat. acid.
of Water		Oxygen 8	—	
49		Dry ac. 40	—	
Chloride of	{	Chlor. 36	—	
Sodium 60		Sodium 24	—	72 Sulph. Soda.

LITHIUM 10, BARIUM 69, (68-7,) STRONTIUM
44, (43-8.)

These elementary bodies possess many interesting characters, but it does not fall within our plan to notice them particularly.

CALCIUM, 20, (20-5.)

The existence of calcium, or the metallic base of lime, was perhaps first demonstrated by Dr. Secbeck. There are two oxides of calcium.

	Calcium.	Oxygen.
Lime, or protox. of Calcium,	20 or 1 atom +	8 = 28
Deutoxide of Calcium,	20 „ +	16 = 36

The combinations of lime with some of the acids form a very extensive and important class of mineral substances.

Nitrate of Lime.—This is a very abundant natural production in the lime-stone caverns in the western parts of the United States, where it occurs in connexion with the nitrate of potash.

Carbonate of Lime.—This occurs in nature under a number of crystalline shapes. It forms extensive mountainous masses, and constitutes a large part of the solid crust of the earth.

Phosphate of Lime.—This salt exists in bones and

the solid parts of animals, in the proportion of 86 per cent.

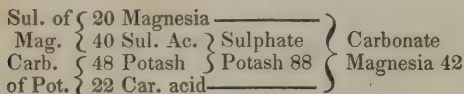
Sulphate of Lime.—This is found abundantly in the mineral kingdom, and is known in the arts under the name of gypsum, selenite, and alabaster.

MAGNESIUM, 12, (12-7.)

Magnesium, the base of magnesia, was first fairly produced by M. Bussy, by the action of potassium on the chloride of magnesium.

Magnesia is the only known oxide of this metal—it is prepared by exposing the carbonate of magnesia to an intense heat, by which the carbonic acid is expelled.

Carbonate of Magnesia is obtained by decomposing the sulphate of magnesia with carbonate of potash—double decomposition ensues, which will be readily seen as follows:



Sulphate of Magnesia or Epsom salt, occurs often in mineral springs; but it is made on a large scale by the action of dilute sulphuric acid or magnesian earths.

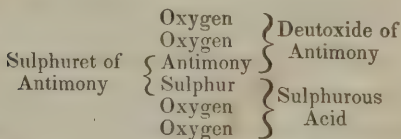
ANTIMONIUM OR ANTIMONY, 64, (64-6.)

This metal is found native; but all the antimony of commerce is derived from the sulphuret. There are at least three oxides which appear to be constituted as follows:

	<i>Antimony.</i>	<i>Oxygen.</i>
Protoxide - - - -	64 or 1 atom	+ 12 = 76
Deutoxide - - - -	64 - - -	+ 16 = 80
Peroxide - - - -	64 - - -	+ 20 = 84

Protoxide of Antimony.—This is made by boiling the sulphuret in muriatic acid. After the sulphuretted hydrogen produced by this process, escapes, the residue is thrown into water, and a white curdy precipitate falls, which is the oxide in question, united perhaps to a little muriatic acid. This by digestion with carbonate of potash, yields the oxide in a state of purity. The principal chemical changes we have already explained under sulphuretted hydrogen. The protoxide of antimony appears to be the active ingredient in the medicinal preparations of which antimony forms a part.

Deutoxide of Antimony or Antimonious Acid.—This is generated when antimony is burnt in the air, or when the sulphuret is exposed to a high heat—in this last case, sulphurous acid and protoxide are first formed; but on continuing the roasting the acid is driven off—the oxide gradually absorbs oxygen and passes into the deutoxide. The following sketch will illustrate some of these changes, the oxygen being derived from the air:

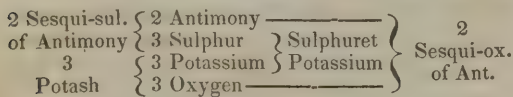


The antimonious acid combines in definite proportions with alkaline substances, and forms the salts called *antimonites*.

Antimonic Acid or the *Peroxide of Antimony*.—This is prepared by digesting the metal in strong nitric acid, expelling the excess of acid by heat, and throwing the solution into water. With alkalies this acid forms the antimoniates.

Antimony and Sulphur.—These elements combine in several definite proportions. The native sulphuret, from which the metal is obtained by heating that mineral with iron filings, is a sesqui-sulphuret, consisting of two atoms of antimony and three of sulphur. The pharmaceutic preparations called the *glass*, the *liver*, and the *crocus* of antimony, are for the most part composed of one atom of the sesqui-oxide and two of the sesqui-sulphuret, but owing to the manner in which they are prepared, their constitution is not uniform.

When sulphuret of antimony is boiled in a solution of potash or soda, a liquid is obtained which deposits after cooling the *kermes mineral*, called so from its resemblance in colour to a reddish insect named kermes. When an acid is added to this solution a still farther precipitate is produced, which is called the *golden sulphuret* of antimony. Several opinions are entertained as to the nature of these precipitates. The following diagram will illustrate the first part of the above process as given by Berzelius—when sesqui-sulphuret of antimony is boiled with potash:



The liquid is now supposed to contain the sesqui-oxide of antimony and the sulphuret of potassium, to-

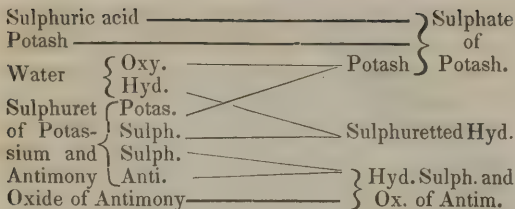
gether with some undecomposed potash and the sulphuret of antimony. The sulphuret of potassium then unites with undecomposed sulphuret of antimony, and the oxide of antimony with undecomposed potash, and both compounds are dissolved by hot water thus:

Potash	}	Sesqui-oxide of Antimony and
Oxide of Antimony		Potash
Sulphuret Potassium	}	Sesqui-sulphuret of Antimony
Sulphuret Antimony		and Sulphuret Potassium

As the solution cools the sesqui-sulphuret of antimony subsides, simply because the solvent power of the sulphuret of potassium, with which it was united, is thereby diminished, and a variable quantity of potash and sesqui-oxide of antimony also falls with this deposit. This is the kermes, and is composed of

Sesqui-sulphuret of Antimony,
 Sesqui-oxide of Antimony,
 And Potash.

The cold solution still contains a double sulphuret of antimony and potassium and the sesqui-oxide of antimony united to potash—on adding sulphuric acid, the sulphuret of potassium, by the decomposition of water, is converted into potash and sulphuretted hydrogen, while the hydrated sulphuret of antimony and the oxide of antimony, which is also separated by the acid from its potash, are thrown down either in combination or in mixture with each other. This is the *golden sulphuret*, differing from the kermes, in the absence of potash, and containing more oxide of antimony. The following sketch will assist in recollecting these changes:



On the preceding explanation the metallic sulphuret is supposed to exist as such in solution, and the compounds are not regarded as *sesqui* combinations. This is done merely for the sake of brevity.

Phosphate of Antimony and Lime.—This preparation is called pulvis antimonialis, or James' powder. It is formed by heating strongly, in an open vessel, one part of sulphuret of antimony and two parts of hartshorn shavings; the heat drives off the sulphur from the sulphuret, and the animal matter from the shavings; the antimony, by absorbing oxygen from the air, passes into the deutoxide, and thus unites to the phosphate of lime of the hartshorn shavings. A better way to form this pharmaceutic compound is to add together in proper proportions calcined bones and protoxide of antimony.

Tartrate of Antimony and Potash.—This compound has been long known in the materia medica under the name of *tartar emetic*. It is made by boiling the protoxide of antimony with a solution of the bitartrate of potash. It is composed of

Tartaric acid,	66 + 2 = 132	or 2 atoms.
Oxide of antimony,	76 + 2 = 152	or 2 atoms.
Potash, - - -	- - - 48	or 1 atom.
Water, - - -	9 + 2 = 18	or 2 atoms.

Tartar emetic is decomposed by many reagents; thus alkaline substances, from their superior attraction for tartaric acid, throw down the oxide of antimony. Sulphuretted hydrogen precipitates the orange sulphuret of antimony. A strong decoction of tea, an infusion of gall nuts, and other similar astringent solutions, form with it a dirty-white precipitate, which is regarded as a compound of tannin and oxide of antimony. This combination is inert, and therefore a decoction of cinchona bark is a good antidote to tartar emetic.

The best method of detecting antimony in mixed fluids, as when tartar emetic is mixed with articles of food, is first to digest them in water acidulated with muriatic or tartaric acids; the former coagulates any animal principle which may be present, and the latter gives complete solubility to all precipitates formed by reagents with tartar emetic, except that caused by the sulphuretted hydrogen. Through the filtered liquid sulphuretted hydrogen is to be passed, when an orange-red precipitate is produced, the sesqui-sulphuret of antimony. Its colour is so peculiar that it cannot readily be mistaken for that of any other sulphuret. But to remove all doubt, put this sulphuret when dried in a glass tube, placed horizontally; transmit through it a current of hydrogen gas; the sulphur is then carried off as sulphuretted hydrogen, and metallic antimony remains.

In its solid state, tartar emetic may be reduced by placing it on charcoal and heating it with a blowpipe flame; it first decrepitates, then chars, and quickly small shining globules like quicksilver will be found in the mass.

CHROMIUM, 28.

This metal was discovered by Vauquelin. It unites to oxygen in two proportions, forming a green oxide and a red acid; the emerald owes its colour to the presence of the first, and the ruby to that of the second. The chromate of potash, from which all the compounds of chromium may be obtained, is made by heating to redness the native oxide of chromium and iron, improperly called the *chromate of iron*, with an equal weight of nitrate of potash, by which means chromic acid is formed; this acid then combines with the potash of the nitre.

Bichromate of Potash.—This beautiful salt is prepared in large quantities at Baltimore for the purposes of the arts, by acidulating the neutral chromate with sulphuric or acetic acid.

Several fatal cases have occurred of poisoning with the saturated solution of this salt. Professor Ducatel recommends as an antidote the exhibition of carbonate of soda or potash, which neutralize the excess of the acid to which the active agency of the salt is principally to be ascribed. The presence of chromate or bichromate of potash in solution may be recognised by adding to one portion the acetate of lead, and to another portion the nitrate of silver; the first causes a rich yellow and the other a deep red or purple precipitate. Any of the chromates may be known by boiling them in muriatic acid mixed with alcohol; in this process the chromic acid is at first set free and then decomposed, a green muriate of the oxide of chromium being generated.

MANGANESIUM OR MANGANESE, 28 (27-7.)

This metal was discovered by Scheele and Gahn. It has a strong affinity for oxygen, and combines with it in the following proportions.

Protoxide,	28 + 8	or	1 + 1 atom
Sesqui-oxide,	28 + 12	„	2 + 3 atoms
Peroxide,	28 + 16	„	1 + 2 „
Red oxide,	28 + 10.66	„	3 + 4 „
Varvacite,	28 + 14	„	4 + 7 „
Manganesious acid,	28 + 24	„	1 + 3 „
Manganesic acid,	56 + 56	„	2 + 7 „

Of all these compounds the peroxide is perhaps the most important. This is the substance which occurs in commerce under the name of the black oxide of manganese. It is found abundantly in nature in large amorphous masses, and sometimes in minute prisms, radiating in groups from a centre. It is used for the purpose of obtaining chlorine and oxygen.

When the peroxide of manganese is heated to redness with its own weight of nitre, a compound is formed called the *mineral camelion*, which, when dissolved in water, undergoes several changes of colour. The green colour is attributed to the manganesite of potash and the red to the manganesate, which salts are formed during the process.

MOLYBDENUM, 48, (47-7,) TUNGSTENUM, 100, (99-7,) COLUMBIUM, 185, TITANIUM, 24, (24-3,) URANIUM, 217.

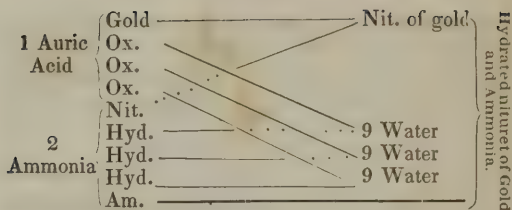
Of the five metallic elements above noticed, little

need be said. They occur rarely in nature, combined with other substances. All of them unite with oxygen and form peculiar acids; most of these combinations are, however, but very imperfectly understood.

AURUM OR GOLD, 200.

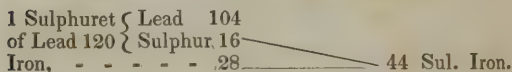
This element has been known and prized from the earliest ages of the world, for few metals combine so many useful properties. It has always been found pure, or united in its metallic state with other bodies. With oxygen it seems to unite in several proportions, but the chemical history of these compounds is as yet very imperfect. Berzelius thinks there are three oxides. His protoxide is obtained by decomposing the protochloride of gold by pure potash; it is of a dark green colour. The deutoxide is purple, and is produced by the combustion of the metal. The peroxide is precipitated by the alkalies from the solution of gold, combined with muriatic acid. It is composed of one atom of gold and three of oxygen, and is the only well ascertained compound of these two bodies; as it has acid properties it is called the *auric acid*.

When the auric acid is kept for some hours in strong ammonia a fulminating compound is formed, the elements of which are in the ratio of one atom of gold, two of nitrogen, six of hydrogen, and three of oxygen. Dumas, who analyzed this substance, supposes these elements are arranged so as to form a hydrated *nituret of gold*, united to ammonia. The following diagram will explain his ideas on this subject.



PLUMBUM OR LEAD, 104, (103-5.)

Lead is one of the earliest metals known. It occurs in nature in several combinations, but that with sulphur is by far the most abundant. It is from this ore, called *galena*, that metallic lead is extracted, either by heat alone, or by the combined action of heat and iron filings. This last process may be thus represented:

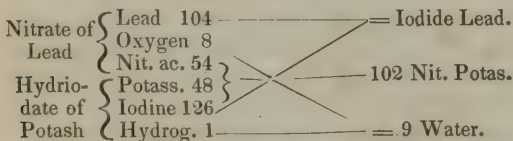


Lead has three degrees of oxidation, and its oxides are constituted as follows:

	Lead.	Oxygen.	
Protoxide,	104 or 1 atom	8	yellow oxide.
Sesqui-oxide,	104	„ 12	red oxide.
Peroxide,	104	„ 16	brown oxide.

The protoxide of lead is the base of all the salts of lead. Many of these are poisonous—the carbonate seems to be the most virulent. The best method of detecting them in suspected fluids is the sulphuretted hydrogen, which throws down the black sulphuret of lead; this being collected on a filter and washed, is to

be digested in dilute nitric acid until the black colour disappears. The solution of the nitrate of lead thus formed is to be dried in a watch glass to expel any excess of nitric acid, and the residue is to be dissolved in cold water. On dropping into this liquid hydriodate of potash, the fine yellow iodide of lead will appear. The last step in the above process may be represented as follows:



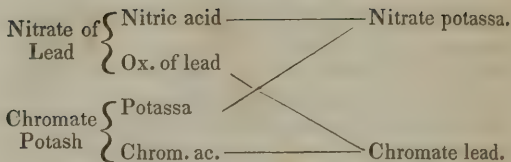
The *sesqui-oxide*, or red lead, is employed in the arts as a paint and in the manufacture of glass.

Carbonate of Lead.—This is the ceruse or white lead of commerce. It may be prepared by adding a solution of carbonate of potash to one of nitrate of lead. On a large scale it is formed by exposing sheet lead to the vapour of vinegar.

Phosphate of Lead may be obtained by adding the phosphate of soda to the nitrate of lead.

Sulphate of Lead is formed by mixing sulphate of soda with a solution of nitrate of lead.

Chromate of Lead is produced by adding chromate of potash to nitrate of lead. The following diagram will illustrate this and the cases of double decomposition hinted at above.



FERRUM, OR IRON, 28.

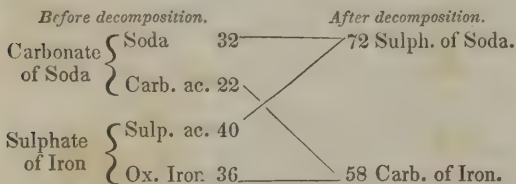
This metal has been known from time immemorial. Iron has a powerful affinity for oxygen; when moisture is present in the air it *rusts*, or oxidates with great rapidity. There are but two definite compounds of these two bodies, which have the following constitution:

	<i>Iron.</i>		<i>Oxygen.</i>
Protoxide,	28	or 1 atom	8 = 36
Sesqui-oxide,	28	,,	12 = 40

The black oxide which was formerly supposed to be the protoxide of iron, has been proved to consist of the protoxide and sesqui-oxide, united together in proportions that are very variable. In studying the metallic oxides it is necessary to distinguish those oxides which are formed by the direct union of oxygen and a metal from those produced by the union of two oxides with each other, and which seem to be allied to *salts* rather than to oxides. The black oxide of iron furnishes an example of this sort of combination. The protoxide and the sesqui-oxide both form salts by uniting to acids. The protoxide is the base of the native carbonate of iron and of the green vitriol of commerce. The black oxide is often called *magnetic iron ore*, and it is principally

this compound which supplies the vast demands for iron.

Carbonate of Iron may be obtained by dissolving 144 grains of the crystallized carbonate of soda and pouring the solution into an ounce of water in which 139 grains of the crystallized green sulphate of iron have been dissolved, collecting the precipitate on a filter. The reaction that takes place is represented in the diagram, the salts being mixed in equivalent proportions, making allowance for the water of crystallization.



The sulphate of soda remains in solution, and the precipitated carbonate is washed on a filter with hot water which has been boiled to expel the air it usually contains. It soon attracts oxygen from the air, and assumes the same appearance as the rust of iron, losing also part of its carbonic acid.—*See Reid.*

Sulphate of Iron is prepared in large quantity for commercial purposes by exposing the native sulphuret of iron to air and moisture, the iron being converted into an oxide and the sulphur into sulphuric acid by attracting oxygen. On the small scale it may be prepared by mixing 6 parts of iron with 10 of sulphuric acid and 60 of water, evaporating the solution in a glass or earthen vessel, after the effervescence arising from the disengagement of hydrogen gas has ceased, till a rod dipped

into it presents appearances of crystallization when held in the air. The solution may then be filtered, and green crystals of the sulphate will be formed as it cools. The rationale of the process is given under *Hydrogen*.

Iron and Cyanogen.

Iron unites to cyanogen and forms the base or radical of a very interesting hydracid, called the hydro-ferrocyanic acid. The base of this compound has never been obtained in an insulated state, but it is composed of

Cyanogen, 3 atoms } or of { Cyanogen, 2 atoms
Iron, 1 atom } Cyanide of Iron, 1 atom

The acid itself consists of one atom of the radical and two of hydrogen.

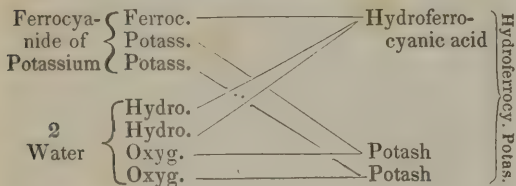
Hydro-ferrocyanic acid is obtained by adding sulphuric acid to the hydro-ferrocyanate of barytes; sulphate of barytes precipitates, and the hydro-ferrocyanic acid remains in solution.

Hydro-ferrocyanate of baryta is prepared by digesting Prussian blue with a solution of pure baryta.

Prussian blue, or the *hydro-ferrocyanate of the peroxide of iron*, is made by mixing the hydro-ferrocyanate of potash with a salt of the peroxide of iron.

Hydro-ferrocyanate of potassa, which may be considered as the parent of all hydro-ferrocyanates, is prepared on a large scale in the arts, by igniting dried blood or other animal matter, such as hoofs and horns, with potash and iron. By the mutual reaction of the elements of these substances, ferrocyanide of potassium is produced, consisting of one atom of ferrocyanogen, or the radical of the hydro-ferrocyanic acid, and two atoms of potassium. When ferrocyanide of potassium

is dissolved in water, a solution of the hydro-ferrocyanate of potassa is formed by the decomposition of the water; two atoms of hydrogen uniting to the ferrocyanogen and forming one atom of hydro-ferrocyanic acid, while two atoms of oxygen unite to the potassium. The following diagram will illustrate this change:



CUPRUM, OR COPPER, 64, (63-2.)

This is one of the ancient metals. It occurs native, often in very large masses, but the principal part of the copper of commerce is derived from the sulphuret. With oxygen copper combines in at least two proportions, and they are constituted as follows:

	<i>Copper.</i>	+	<i>Oxygen.</i>	
Protoxide,	64	+	8	= 72 red oxide.
Peroxide,	64	+	16	= 80 black oxide.

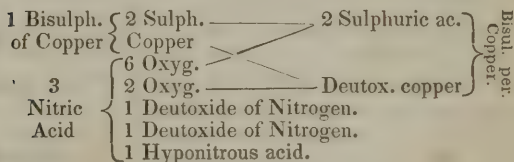
Both these compounds are found native; the red oxide is worked for the metal, and is a valuable ore, at Somerville, in New Jersey.

Sulphurets of Copper.—These compounds are the *copper glance* and the *copper pyrites* of mineralogists; from the first the metal is generally extracted.

Carbonate of Copper.—This forms the beautiful green mineral called *malachite*. The paint named *verditer* is also a carbonate.

Sulphate of Copper, or Blue Vitriol.—It is prepared in the arts by roasting the native sulphuret so as to bring both its elements to a maximum of oxidation. It contains two atoms of sulphuric acid and one of the peroxide of copper.

The best method of detecting copper in suspected fluids is to pass into them sulphuretted hydrogen. The black sulphuret of copper precipitates, which is to be collected and heated to redness to carbonize organic matter, and then digested with a little nitric acid. Sulphate of copper is thus formed, which, when dried and diluted with water, is rendered deep blue by ammonia. The following diagram will explain the chemical changes in the first part of the above process, supposing that the nitric acid is digested on the bisulphuret of copper.



Albumen is the best antidote to administer in cases of poisoning with copper.

MERCURIUM, OR MERCURY, 200.

Mercury is distinguished from all other metals by being fluid at the ordinary temperature of the air. It is found native in all quicksilver mines, along with the sulphuret, which is the common ore. From this ore the mercury is extracted by heating it with iron filings.

Bisulph. of Merc. } Mercury 200
 or Cinnabar, 232 } 2 Sulphur 32 } 88 Proto-sulphuret
 2 Iron, - - - - 56 } of Iron.

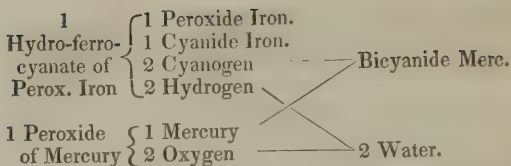
Mercury unites to oxygen in two proportions, and the oxides are thus constituted:

	<i>Mercury.</i>	<i>Oxygen.</i>	
Protoxide,	200 +	8 =	208 black oxide.
Peroxide,	200 +	16 =	216 red oxide.

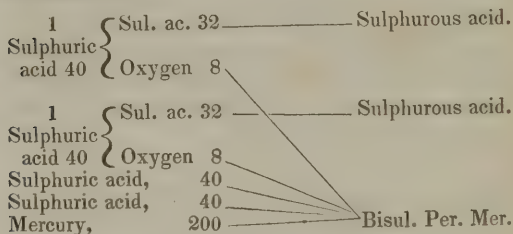
The peroxide of mercury, or *red precipitate*, is commonly prepared by dissolving the metal in nitric acid, and exposing the salt so formed to a temperature just sufficient to expel the whole of the acid. The oxygen in the protoxide of mercury is very feebly united to the metal, for it resolves itself into fluid mercury and the red precipitate, even when exposed to the light. This change may be shown as follows:

2 Protoxide of Mercury $\left\{ \begin{array}{l} \text{Oxygen } 8 \\ \text{Oxygen } 8 \\ \text{Mercury } 200 \\ \text{Mercury } 200 \end{array} \right\} 216 \text{ Red Precipitate.}$

Bicyanide of Mercury.—This compound is prepared by boiling pure hydro-ferrocyanate of the peroxide of iron with the peroxide of mercury. In this process Dr. Turner remarks that the oxygen of the oxide of mercury unites to the hydrogen and the iron of the hydro-ferrocyanic acid, while the metallic mercury combines with the cyanogen. The brown matter which falls, he observes, is the peroxide of iron. It appears from the following diagram that cyanide of iron, as well as peroxide of iron, must remain undecomposed.



Bisulphate of Peroxide of Mercury is prepared by boiling to dryness sulphuric acid and mercury. Four atoms of acid are required to convert the mercury into this salt. The following diagram represents the theory of its formation.



PLATINUM, 98, (98-6.)

This valuable metal appears to have been discovered by Mr. Wood. It is only found in the metallic state, usually in small grains, associated with a number of other metals. It is the heaviest substance known. With oxygen it combines in two proportions:

	Platinum.	Oxygen.	
Protoxide,	98	+	8 = 106.
Deutoxide,	98	+	16 = 114.

Palladium, Iridium, Rhodium, Osmium, Pluranium, and Rhutenium, are metallic bodies, all contained in the

ores of platinum, but they have hitherto been obtained in very small quantities, and the properties of most of them are but little known.

COBALTUM, OR COBALT, 29, (29-5,) AND NICKELUM, OR NICKEL, 29, (29-5.)

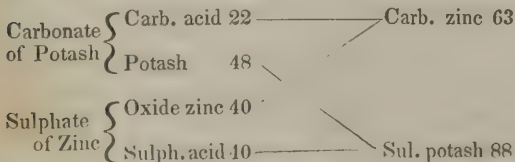
These two metals are almost always found in meteoric iron, and the ores which yield one are commonly found to contain the other. Both of them, like iron, may be rendered permanently magnetic. They are both susceptible of two degrees of oxidation; the oxygen in the two oxides being as 1 to 1.5. Cobalt is a brittle metal, but nickel is both malleable and ductile.

ZINCUM, OR ZINC, 32, (32-5.)

This element seems to have been first described by Agricola. The zinc of commerce is obtained from the native sulphuret and the carbonate. It unites to oxygen in but one proportion, which is constituted of one atom of the metal and one of oxygen.

Sulphuret of Zinc.—This is found abundantly in nature, and is composed of one atom of each of its constituents; it is called blende.

Carbonate of Zinc.—This is the *calamine* of mineralogists, and it is made artificially by adding carbonate of potash to sulphate of zinc.



Sulphate of Zinc.—This is often called white vitriol. It is made for commercial purposes by roasting the native sulphuret in a furnace, so as to bring its elements to a maximum of oxidation.

Sulphate of zinc, or white vitriol, when administered in the dose of a scruple, is the most immediate emetic we possess. It is very frequently employed in the treatment of poisoning, and its presence therefore may sometimes interfere with various medico legal analyses. The mode of detecting the salts of zinc is to add the carbonate of ammonia to a solution of the pure salt; the white carbonate of zinc is thrown down, which is dissolved in an excess of carbonate of ammonia, and is not again precipitated by boiling. A stream of sulphuretted hydrogen also occasions a *white* precipitate; the sulphuret of zinc, which is very characteristic. When the sulphate of zinc has been mixed with animal and vegetable substances the action of the tests is somewhat modified: in such circumstances Dr. Christison advises to strain the mixture through gauze, then to acidulate with acetic acid, and afterwards filter the solution. The acetic acid dissolves any oxide of zinc that may have been thrown down in union with the animal matter. Through this cool, concentrated, filtered and neutral solution sulphuretted hydrogen is to be passed; the white or grayish precipitate thus produced is to be washed and dried, and heated to redness in a tube. When cooled, strong nitric acid is added, which dissolves the zinc and leaves the sulphur. The carbonate of ammonia, when added to this nitric solution diluted, will then precipitate the white carbonate. The action of heat on this carbonate ought to be particularly relied upon.

Cadmium is a rare metal, discovered by Stromeyer, in the oxide of zinc. .

BISMUTHUM, OR BISMUTH, 71.

This metal has been long known; it is mentioned by Paracelsus. It is found native, and the metal of commerce is derived from the ore by simple fusion, in order to separate the stony matter to which it is usually attached. Next to tin it is the most fusible of the solid metals. With oxygen it unites in but one proportion; one atom of each of the elements compose the oxide.

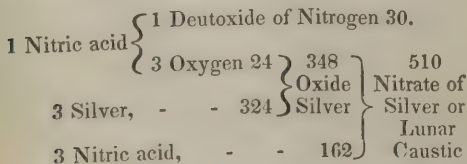
Nitrate of Bismuth, thrown into water, deposits a beautifully white powder called magistery of bismuth, which is used as a cosmetic.

ARGENTUM, OR SILVER, 108.

Silver was perhaps the first metal known. It has been found native in a state of purity in immense masses. With oxygen it unites in but one proportion, which compound is formed by one atom of each element.

Sulphuret of Silver, one of the ores, is composed of one of silver and one of sulphur.

Nitrate of Silver is the most important salt of this metal. It is prepared by digesting silver in nitric acid; a portion of the acid yields oxygen to the silver, and the oxide thus formed unites to some undecomposed nitric acid. The diagram illustrates this change:



CERIUM, GLUCINUM, YTTRIUM AND THORINUM.

These metals have only been found in small quantity, and their properties have not been fully investigated.

ALUMINUM, 13, (13.7.)

This metal was discovered by Sir H. Davy. It is the base of alumina, which is one of the most abundant productions of nature. It forms not only the principal ingredient in all plastic clays, but some of the most beautiful gems are composed of nearly pure alumina; the ruby and the sapphire are examples of this kind. Alumina is the sesqui-oxide of aluminum, and is the only compound of its constituents known; 25 is its atomic weight or combining proportion.

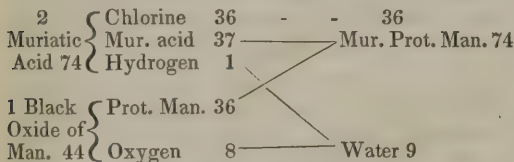
Sulphate of Alumina and Potassa.—This double salt is the alum of commerce: it is composed of

Sesqui-sulphate of Alumina,	-	2 atoms
Sulphate of Potash, - - -	-	1 atom
Water, - - - - -	-	24 atoms

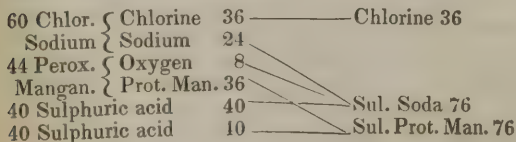
PART II.

CHLORINE AND ITS COMBINATIONS WITH ELEMENTARY BODIES.

Chlorine gas was discovered by Scheele. It is obtained by the action of muriatic acid on the black oxide of manganese. The following sketch will exhibit the theory of its formation:



Chlorine is also procured by adding sulphuric acid to a mixture of chloride of sodium, (common salt,) and the black oxide of manganese. The chemical changes may be represented as follows:



The water with which the sulphuric acid is always combined is not taken into account in the above rationale, and the chloride of sodium is not supposed to be in solution. During the process as it occurs in the arts, the muriate of soda, and not chloride of sodium, occurs in the mixture. The chemical changes as expressed in the preceding diagram, will be a little altered, as in the following; the oxygen of the manganese uniting to the hydrogen of the muriatic acid.

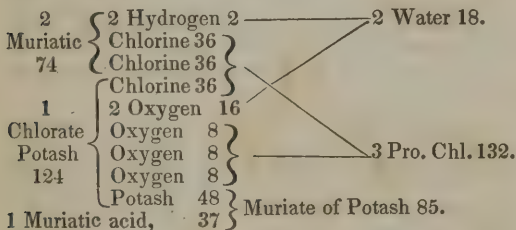
69 Mur.	{ Chlorine	36	-	-	-	-	36
of Soda	{ Soda	32					
	{ Hydrogen	1					
44 Perox.	{ Oxygen	8					
Mang.	{ Prot. Man.	36					
40 Sulphuric acid,		40					
40 Sulphuric acid,		40					
						Water,	9
						Sulph. of Soda	72
						Sul. Prot. Man.	76

The following table exhibits some of the most important compounds of chlorine with the non-metallic substances previously described.

	By volume.		By weight.	
	<i>Chlor.</i>	<i>Oxyg.</i>	<i>Chlor.</i>	<i>Oxyg.</i>
Protoxide of Chlorine,	36	+	8	2
Peroxide of Chlorine,	36	+	32	2
Chloric acid,	36	+	40	2
Perchloric acid,	36	+	56	2
	<i>Chlor.</i>	<i>Nit.</i>	<i>Chlor.</i>	<i>Nit.</i>
Chloride of Nitrogen,	144	+	14	4
	<i>Chlor.</i>	<i>Hyd.</i>	<i>Chlor.</i>	<i>Hyd.</i>
Muriatic acid,	36	+	1	1
	<i>Chl.</i>	<i>Car. Ox.</i>	<i>Chl.</i>	<i>Car. Ox.</i>
Chloro-carbonic acid,	37	+	14	1
	<i>Chlor.</i>	<i>Cyan.</i>	<i>Chlor.</i>	<i>Cyan.</i>
Chloride of Cyanogen,	36	+	26	1

CHLORINE AND OXYGEN.

Protoxide of Chlorine.—This gas was discovered by Sir H. Davy. It is made by the action of muriatic acid on the chlorate of potash, and its formation arises from the fact that the muriatic and the chloric acids mutually decompose each other. Three atoms of muriatic acid and one atom of the chlorate of potash are used; one atom of muriatic acid unites to the potash of the salt, and thus liberates an atom of chloric acid, which instantly reacts on two atoms of muriatic acid, and forms two atoms of water and three atoms of the protoxide of chlorine. The following diagram will make these changes more evident:



Peroxide of Chlorine.—This compound was discovered by Sir H. Davy and Count Stadion. It is formed by the action of sulphuric acid on the chlorate of potash. The chemical changes which take place may be explained by the following diagram. Three atoms of chlorate of potassa and two of sulphuric acid are employed:

2	Chlorine	36	} 2 Perox. Chlorine 136.
Chlorate of	Chlorine	36	
Potash	4 Oxygen	32	
248	4 Oxygen	32	
	2 Oxygen	16	
2 Sulphuric acid,	2 Potash	96	} Sulph. Potassa.
		80	
1 Chlorate of Potash,	124		Perchlo. Potassa.

The whole products of the above decomposition are, therefore, two atoms of peroxide of chlorine, two atoms of sulphate of potash, and one atom of the perchlorate of potash.

Chloric acid.—This acid was first observed by Mr. Chenevix. Gay Lussac first obtained it in a separate state, by adding a weak solution of sulphuric acid to the chlorate of baryta; the insoluble sulphate of baryta subsides, and the chloric acid remains in solution. It is hardly necessary to add the following diagram to exhibit this change:

1 Chlorate of	{ Chloric acid,	- - - -	76
Baryta 145	{ Baryta 69 }		
Sulphuric acid,	- - 40 }	Sulphate of Baryta,	109

Chlorate of Potash.—This interesting salt was discovered by Bertholet. It is made by passing chlorine through a concentrated solution of pure potash. Six atoms of chlorine, five atoms of water, and six atoms of potash, are necessary for its production, and the products after the operation are five atoms of the muriate and one atom of the chlorate of potash; the muriate remains in solution, and the chlorate crystallizes in four or six sided scales.

Rationale of the above process.—Five atoms of the oxygen of the water unite to one atom of chlorine and

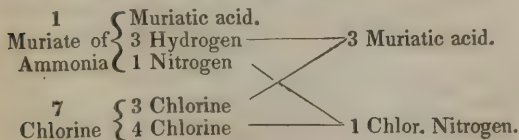
form one atom of chloric acid; at the same moment that five atoms of its hydrogen unite to five atoms of chlorine, and form five atoms of muriatic acid. Both acids combine with the potash, producing one atom of chlorate and five atoms of the muriate of potash. The following table shows the proportions in which the chlorine and the elements of water unite:

1 Hydrogen	+	1 Chlorine	=	1 Muriatic acid	=	37.
1 Hydrogen	+	1 Chlorine	=	1 Muriatic acid	=	37.
1 Hydrogen	+	1 Chlorine	=	1 Muriatic acid	=	37.
1 Hydrogen	+	1 Chlorine	=	1 Muriatic acid	=	37.
1 Hydrogen	+	1 Chlorine	=	1 Muriatic acid	=	37.
5 Oxygen	+	1 Chlorine	=	1 Chloric acid	=	76.

Perchloric acid.—This acid was discovered by Count Stadion. It is made from the perchlorate of potash by the addition of dilute sulphuric acid, aided by heat.

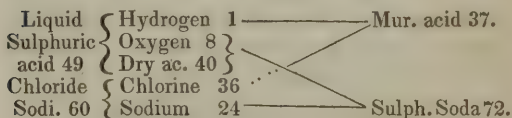
CHLORINE AND NITROGEN.

Chloride of Nitrogen.—This compound was discovered by Dulong. It is made by inverting a tall wide-mouthed jar of chlorine gas in a strong solution of muriate of ammonia, which salt is decomposed by the chlorine; the hydrogen of the ammonia unites to one portion of the chlorine and forms muriatic acid, while the nitrogen combines with another portion and generates the chloride of nitrogen. The diagram will illustrate the chemical changes during this process.

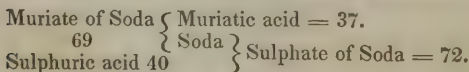


CHLORINE AND HYDROGEN.

Muriatic acid.—This acid, in its gaseous state, appears to have been first noticed by Dr. Priestley. It is made by adding sulphuric acid to the chloride of sodium; one atom of water in the acid is resolved into its elements, the hydrogen unites to the chlorine and forms muriatic acid, while the oxygen goes to the sodium and generates soda, which combines with the sulphuric acid and forms sulphate of soda. The water contained in the liquid sulphuric acid is therefore essential to the process. The following diagram exhibits these changes:

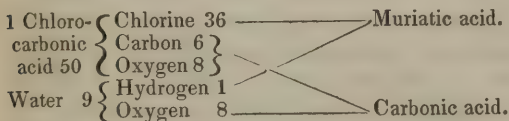


When chloride of sodium is dissolved in water it becomes the muriate of soda, the hydrogen uniting to the chlorine forming muriatic acid, and the oxygen combining with the sodium to form soda; muriate of soda is therefore always generated when chloride of sodium is in solution. When sulphuric acid is added to a solution of chloride of sodium to form muriatic acid the changes produced may be expressed as follows:

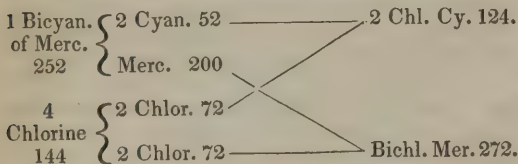


Chloro-carbonic acid.—This compound was discovered by Dr. John Davy. It is formed by exposing a mixture of equal measures of dry chlorine and carbonic oxide to

sunshine; rapid but silent union takes place, and they contract to half their volume. This acid unites to four times its volume of ammoniacal gas, forming a white solid, the chloro-carbonate of ammonia. Water decomposes chloro-carbonic acid, producing carbonic and muriatic acids. The annexed diagram will illustrate this change:



Chloride of Cyanogen.—This compound was first noticed by Bertholet. It is made by exposing the bicyanide of mercury, moistened with water, to the action of chlorine; bichloride of mercury and chloride of cyanogen are the products. The following sketch illustrates the theory and the composition of the products:



METALLIC CHLORIDES.

Chlorine has a strong affinity for metallic substances, and they may in most cases be made to unite directly together. All the chlorides, except the proto-chloride of mercury, or calomel, and the chloride of silver, are soluble in water; and as most chemists imagine, these

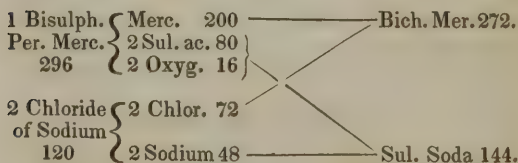
become muriates, the hydrogen combining with the chlorine and the oxygen with the metal. The metallic chlorides are again produced from these solutions by the application of heat, the hydrogen and the oxygen again uniting so as to form water, which escapes.

CHLORIDES OF MERCURY.

Chlorine combines with mercury in two proportions, forming the protochloride, or calomel, and the bichloride, or corrosive sublimate. These compounds are analogous in their composition to the oxides of mercury; their elements are united in the following ratio:

	<i>Mercury.</i>		<i>Chlorine.</i>	
Protochloride,	200 or one atom	+	36	= 236
Bichloride,	200	,,	+ 72	= 272

Bichloride of Mercury.—This compound is prepared for medical purposes by subliming a mixture of the bisulphate of the peroxide of mercury and common salt, or the chloride of sodium. The diagram exhibits the nature of the action which takes place:

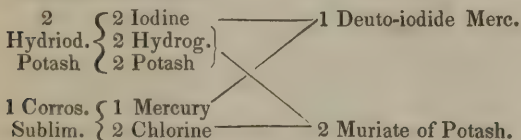


In this process the bichloride condenses on the top of the subliming vessel in a crystalline cake, and sulphate of soda remains at the bottom. The presence of mercury in fluids supposed to contain corrosive subli-

mate may be detected by digesting them with pure potash. The deutoxide of mercury which subsides is to be separated, dried, and sublimed in a glass tube, when metallic globules will appear lining the cavity of the tube.

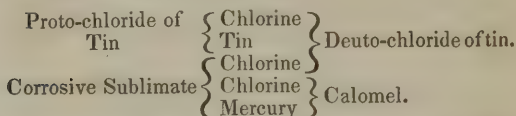
Rationale.—The bichloride, on being dissolved, is changed to the bimuriate of the peroxide of mercury; the potash combines with the muriatic acid, and the peroxide of mercury precipitates; heat then expels the oxygen, and the metal remains.

The hydriodate of potash precipitates mercury from corrosive sublimate, as a rich red deuto-iodide. The solutions, however, must be pure. The theory may be illustrated as follows:



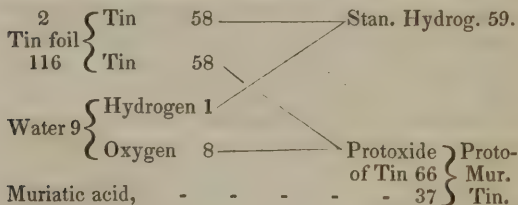
When the poison is mixed with organic substances, then the solution, without previous filtration, is to be agitated with about one-fourth of its volume of ether, which separates the poison from the aqueous part and rises to the surface. This ethereal solution is then to be evaporated on a watch glass, the residue dissolved in hot water, and then, on adding to this a hot solution of the proto-muriate of tin, metallic mercury will be precipitated. The action of proto-muriate of tin on the bichloride of mercury, so as to produce the metal, may be thus explained. When the first portions are added a white powder is thrown down, which is calomel, one atom of chlorine leaving the corrosive sublimate

and uniting to the proto-chloride of tin, converting it into the deuto-chloride, thus:



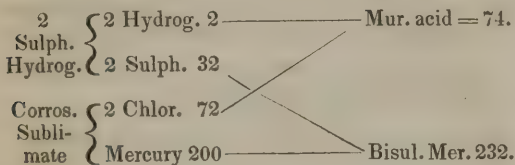
As the tin has a stronger affinity for the chlorine than the mercury, this change continues until all the chlorine leaves the calomel and metallic mercury is revived. If we consider the tin in the above experiment as the muriate of the protoxide, and the corrosive sublimate as the muriate of the deutoxide of mercury, then the proto-muriate of tin, from its powerful deoxidizing agency, abstracts the oxygen from the peroxide of mercury, and thus revives the metal.

The proto-muriate of tin used in the process above, is readily made by pouring strong muriatic acid on tin foil; heat is applied, and the solution must be kept from the air. In this experiment water is decomposed, its hydrogen escapes, perhaps as stanuretted hydrogen, and the oxygen unites to the tin.

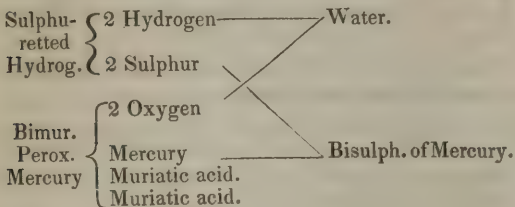


Sulphuretted hydrogen is an exceedingly delicate test for corrosive sublimate. The black deuto-sulphuret

of mercury is formed by its action on the poison in the following manner:



If the poison in solution is considered as a muriate of an oxide, then the rationale is as follows:

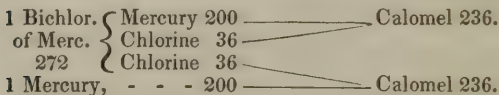


Corrosive sublimate in solution may also be detected by placing a drop of the suspected liquid on a gilt button, and then touching it with a penknife or any piece of iron; a white spot or an amalgam of gold will instantly appear at the place where the iron and the gilding were in contact.

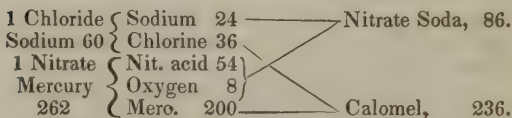
Corrosive sublimate is converted into calomel by many animal and vegetable solutions, muriatic acid being liberated at the same time; albumen produces this change instantly; the white of eggs is therefore a certain antidote to this poison, if immediately administered.

Proto-chloride of mercury, or calomel.—This important preparation is commonly made by subliming a mixture

of one atom or equivalent of corrosive sublimate and one atom of fluid mercury which has been previously triturated till the metallic globules entirely disappear. A diagram will show clearly the nature of the change:

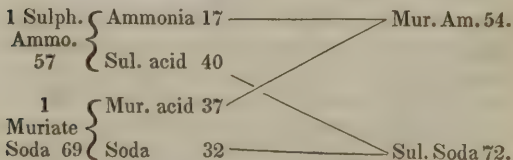


When first prepared, it always contains a little corrosive sublimate; it should therefore be pulverized and well washed before it is employed. Calomel may also be prepared by mixing muriatic acid, or any soluble muriate, with a solution of the nitrate of the protoxide of mercury. The following diagram exhibits the action of chloride of sodium on nitrate of mercury.



MURIATE OF AMMONIA.

This valuable salt, the oldest of all the ammoniacal salts, is most commonly prepared by decomposing the sulphate of ammonia by the muriate of soda. The changes produced may be represented as follows:



PART III.

IODINE AND ITS COMBINATIONS WITH ELEMENTARY BODIES.

IODINE was discovered by M. Courtois. It is obtained from the dark residual liquor left in the vessels after the carbonate of soda crystallizes, from the ashes of sea weeds. This liquor contains a considerable quantity of hydriodic acid, united to potash or soda; by adding sulphuric acid and peroxide of manganese, the iodine is produced, which must be collected in cool receivers. The following diagram will illustrate the theory of its production:

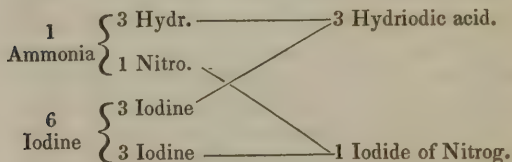
Hydriodate of Soda	{	Iodine	_____	126
		Hydrogen	1	Water 9
		Soda	32	
Peroxide of Mang. 44	{	Oxygen	8	Sul. Soda 72
		Prot. Man.	36	
Sulphuric acid			40	Sul. Prot. Man. 76
Sulphuric acid			40	

The following table presents a view of the constitution of some of the compounds of iodine.

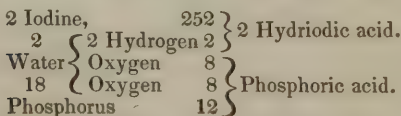
	<i>Iodine.</i>		<i>Oxygen.</i>
Iodic acid,	126 or one atom	+	40 = 166
	<i>Iodine.</i>		<i>Nitrogen.</i>
Iodide of Nitrogen,	378 or three atoms	+	14 = 392
	<i>Iodine.</i>		<i>Hydrogen.</i>
Hydriodic acid,	126	+	1 = 127

Iodic acid was discovered by Davy and Gay Lussac. It is made by decomposing a solution of iodate of soda with sulphuric acid.

Iodide of Nitrogen.—This compound is easily made by triturating iodine in a strong solution of ammonia; the alkali is decomposed, its elements unite to different portions of iodine, and form hydriodic acid and iodide of nitrogen. The diagram will illustrate the change:



Hydriodic acid.—This acid gas is made by adding phosphorus to moistened iodine; mutual decomposition ensues, the oxygen of the water unites to the phosphorus and the hydrogen with the iodine. The diagram will exhibit the theory of the changes:



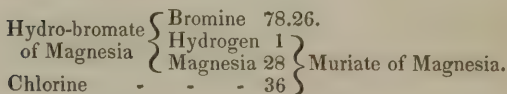
Hydriodate of Potassa.—This salt exists only in solution; it becomes the iodide of potassium in the act of

crystallizing. It is made by adding a hot solution of pure potassa to as much iodine as it will dissolve; the iodate and the hydriodate of potassa will thus be quickly generated. The rationale of this process is the same as that given for generating the chlorate of potash; substituting iodine for chlorine. The mixed iodate and hydriodate of potash are then dried and exposed to a low red heat in a platinum crucible; this converts the whole mass into the iodide of potassium; the oxygen both of the iodic acid and of the potassa escaping in the same manner as when the chlorate of potassa is subjected to a high temperature.

PART IV.

BROMINE AND FLUORINE.

BROMINE was discovered by M. Balard. It exists in sea water, in the form of the hydro-bromate of magnesia. It is prepared by passing a current of chlorine through bittern, or the uncrystallizable residue left after common salt has been removed from it. The chlorine decomposes the hydrobromic acid, uniting with the hydrogen and thus liberating the bromine. This change may be illustrated as follows:



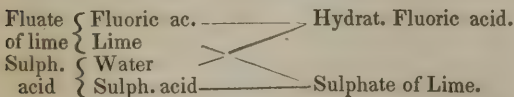
The bromine is separated from the solution by means of heat, or by the addition of sulphuric ether.

Bromine is so analogous to chlorine and iodine in its chemical relations and agencies, that we shall merely add the following table, showing some of its combinations:

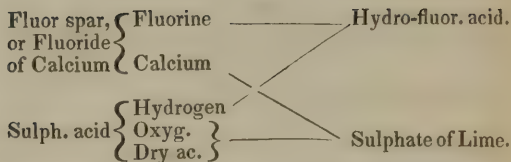
	<i>Bromine.</i>	<i>Oxygen.</i>	
Bromic acid,	78 or one atom	+	40 = 118
	<i>Bromine.</i>	<i>Hydrogen.</i>	
Hydro-bromic acid,	78 or one atom	+	1 = 79
	<i>Bromine.</i>	<i>Chlorine.</i>	
Bromide of Chlorine,	78 or one atom	+	36 = 114
	<i>Bromine.</i>	<i>Iodine.</i>	
Bromide of Iodine,	78 or one atom	+	126 = 204

FLUORINE.

Fluorine has never been obtained in a separate state. When the mineral called *fluor spar* is acted upon by strong sulphuric acid, the compound called *fluoric acid* is produced. This was discovered by Scheele. Some chemists imagine that this acid is a compound of a certain inflammable principle called *fluorine* and oxygen, and that the fluor spar from which it is produced is the fluat of lime. On this view of its constitution the following is the rationale of its production:



A different and, perhaps, a more correct view is taken of this subject. According to this theory, fluor spar is a compound of fluorine and calcium, and the fluoric acid is produced by the union of hydrogen with fluorine. When sulphuric acid is poured upon the fluat of lime, the following is the theory of the changes which occur:



The chemical changes are the same as when sulphuric acid is added to chloride of sodium.

I N D E X .

ACID, Antimonic,	51	ANTIMONY,	
Antimonious,	50	Phosphate of,	53
Arsenic,	41, 42	Tartrized,	53
Arsenious,	41	ARSENIC,	41
Auric,	57	Sulphuret of,	43
Carbonic,	19	Tests for,	41, 42
Chloric,	72	BLUE, Prussian,	62
Chloro-carbonic,	76	BROMINE,	86
Croconic,	22	BROMATES,	86
Fluoric,	87	CALAMINE,	67
Formic,	27	CALCIUM,	48
Hydriodic,	84	CALOMEL,	81
Hydro-chloric,	72	CARBON,	17
Hydro-ferrocyanic,	62	CARBURETTED HYDROGEN,	
Hydro-fluoric,	88		27, 29
Hypo-carbonic,	21	CAUSTIC, lunar,	69
Hypo-nitrous,	10	CHLORATES,	74
Hypo-phosphorous,	31	CHLORINE,	71
Hypo-sulphuric,	37	and Cyanogen,	72
Hypo-sulphurous,	37	and Hydrogen,	72
Iodic,	84	and Nitrogen,	72
Nitric,	12	and Oxygen,	72
Nitrous,	11	CHROMIUM,	55
Oxalic,	21	COPPER,	63
Phosphoric,	30	Carbonate,	63
Phosphorous,	31	Oxides of,	63
Prussic,	25	Sulphurets of,	62
Pyro-phosphoric,	30	Sulphate of,	64
Sulphuric,	34	Tests for,	64
Sulphurous,	36	CYANOGEN,	22
ALUMINA,	70	and Oxygen,	23
AMMONIA,	15	and Hydrogen,	25
ANTIMONY,	49	EMETIC, Tartar,	53
Oxides of,	50	FIRE DAMP,	29
Sulphurets of,	51	FLUORINE,	87

GOLD,	57	NICKEL,	67
Oxides of,	57	Oxides of,	67
Nituret of,	58	NITRE,	44
HYDROGEN,	13	NITROGEN,	7
Oxides of,	14, 15	Oxides of,	8
Arsenuretted,	42	With Hydrogen,	15
Carburetted,	27	OLEFIANT GAS,	27
Phosphuretted,	32	OXYGEN,	5
Sulphuretted,	38	PHOSPHORUS,	29
IODIDE of Nitrogen,	84	With Hydrogen,	32
IODINE,	83	With Iodine,	84
and Hydrogen,	84	With Oxygen,	30
and Oxygen,	84	PLATINUM,	66
IRON,	60	Oxides of,	66
Carbonate of,	61	POTASH,	44
Oxides of,	60	Carbonate of,	45
Sulphate of,	61	Chromate of,	55
IRON and CYANOGEN,	62	Nitrate of,	44
LEAD,	58	Sulphate of,	45
Carbonate of,	59	Sulphuret of,	45
Chromate of,	59	PRUSSIAN BLUE,	62
Oxides of,	58	SILVER,	69
Iodide of,	59	Nitrate of,	69
Phosphate of,	59	Oxide of,	69
Sulphate of,	59	Sulphuret of,	69
Tests for,	59	SODA,	46
LIME,	48	Carbonate of,	46
Carbonate of,	48	Phosphate of,	46
Nitrate of,	48	Sulphate of,	47
Phosphate,	48	SULPHUR,	33
Sulphate,	49	With Hydrogen,	38, 40
LUNAR CAUSTIC,	69	With Oxygen,	34, 36, 37
MAGNESIA,	49	TIN,	43
MANGANESE,	58	Oxides of,	43
Oxides of,	58	UREA,	25
MERCURY,	64	WATER,	14
Oxides of,	64	ZINC,	67
Chlorides of,	78	Carbonate of,	5.
Cyanide,	65	Oxide of,	67
Iodides,	79	Sulphate of,	68
Sulphate of,	66	Sulphuret of,	67



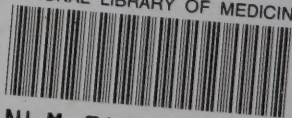
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